CDC
Workplace Safety and Health

A Compendium of NIOSH Mining Research

2002

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

NIOSH

A COMPENDIUM OF NIOSH MINING RESEARCH 2002

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

December 2001

ORDERING INFORMATION

Copies of National Institute for Occupational Safety and Health (NIOSH) documents and information about occupational safety and health are available from

NIOSH–Publications Dissemination
4676 Columbia Parkway
Cincinnati, OH 45226-1998

FAX: 513-533-8573
Telephone: 1-800-35-NIOSH
(1-800-356-4674)
E-mail: pubstaft@cdc.gov
Web site: www.cdc.gov/niosh

DHHS (NIOSH) Publication No. 2002-110

FOREWORD

The mining community serves the needs of our Nation in virtually every aspect of our daily lives by providing the materials we use for construction, electronics, manufacturing, energy, agriculture, medicine, and electricity. This industry has demonstrated time and time again an almost unbelievable ability to rise to any and all challenges it faces. Productivity has increased over the past 20 years to levels never before imagined, and the industry operates in one of the most difficult and challenging environments imaginable. The professionalism and pride of our mine workers are unmatched throughout the world, and our mining community is held in the highest regard around the globe. Interactions with mining professionals from other countries have always left me with a deep feeling of respect for what our mining community accomplishes.

The recent tragedy we faced with the coal mine explosion in Alabama is a reminder to all of us about the dangers of rock and mineral extraction. The miners who lost their lives in the explosion included a group that went back to the working area of the mine in an attempt to rescue others. In the mining environment, all workers tend to be first responders and are always concerned about the welfare of their brothers and sisters. While we have achieved great success in almost eliminating mine explosions, we must be forever vigilant to ensure that changing geological conditions do not compromise the safety of mining operations. We are mining at deeper levels than ever, producing rocks and minerals at far greater rates, and operating increasingly complex mining systems, all in an environment that is best described as challenging and hostile. In order to ensure the safety and health of our precious resource—the mine worker—we must all work together toward the common goal of protecting the worker.

The NIOSH mining research program will continue to serve the needs of the mining community by being a strong advocate for safety and health. Our goal is the protection of the mine worker, and we will continue to conduct research toward the ultimate goal of ensuring that mining personnel are as healthy at the end of their careers as they were at the beginning. The mining research program will address all research areas that have been identified as important to the mining community, and I am proud of our recent accomplishments, many of which are identified in this report. We certainly face a number of challenges in the near future, including loss of experienced mine workers due to retirement, an influx of new, inexperienced workers, more challenging mining conditions, and a global economy that requires extremely efficient and highly productive operations. As the mining community has repeatedly demonstrated in the past, they will rise to the challenges they face, and NIOSH will be there with them.

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

CONTENTS

CONTENTS—Continued

A subject's hearing is assessed in the auditory test lab.

HEARING LOSS PREVENTION

INVESTIGATION OF TECHNOLOGY FOR HEARING LOSS PREVENTION

RESEARCHER: David C. Byrne

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

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

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

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

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

The recently completed auditory research facility is now under-going the accreditation process conducted by the National Institute of Standards and Technology under the National Voluntary Laboratory Accreditation Program. Experiments are planned to investigate the factors that affect a miner's ability to hear hazard and warning sounds (e.g., roof working, alarm signals, spoken communications, etc.). A service contract has been initiated to record and digitally store samples of typical warning sounds heard in an underground coal mine. This information will be analyzed in the lab to develop recommendations that can be offered to the mining community regarding correct earplug/earmuff usage to maximize the recognition of hazard and warning sounds while adequately protecting the miners' hearing.

BIBLIOGRAPHY

Byrne DC, Driscoll DP [1998]. Acoustical considerations for effective emergency alarm systems in an industrial setting (part 1). Milwaukee, WI: Council for Accreditation in Occupational Hearing Conservation, Update *9*(3).

Byrne DC, Driscoll, DP [1998]. Acoustical considerations for effective emergency alarm systems in an industrial setting (part 2). Milwaukee, WI: Council for Accreditation in Occupational Hearing Conservation, Update *9*(4).

NIOSH [1994]. The NIOSH compendium of hearing protection devices. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 95-105.

A noise survey was done at this large surface coal mine.

CROSS-SECTIONAL SURVEY: NOISE EXPOSURE PATTERNS/SOURCES

RESEARCHER: Eric R. Bauer, Ph.D.

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

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

RESEARCH SUMMARY: Overexposure to noise is a serious problem for U.S. mine workers. Every day, 80% of the Nation's miners go to work in an environment where the time-weighted average (TWA) noise levels exceed 85 dBA. Moreover, 25% of the miners are exposed to a TWA noise level that exceeds 90 dBA. Baseline information that provides a current and systematic characterization of worker noise exposure patterns and mining noise sources is needed. This research is essential to develop effective intervention strategies targeting engineering controls for noisy equipment and hearing protection practices and to help ensure that the hearing of miners is preserved, that future hearing loss is prevented, and that the quality of life of the Nation's miners is enhanced.

The approach of this research is to conduct a cross-sectional field study of the noise exposure of mine workers. This includes 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 taking full-shift noise exposure measurements using time-resolved dosimeters, combined with worker task observations. In addition, noise level profiles of various mining machines will be obtained using handheld sound level meters.

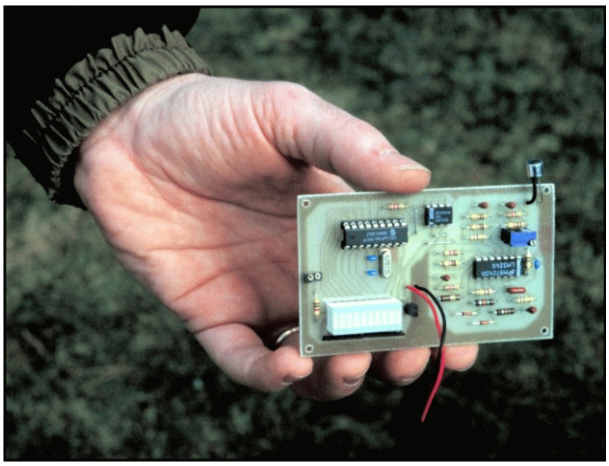
Recent project emphasis has been focused on large surface coal mines and coal prep plants. Noise surveys have been completed at four surface coal mines, four coal prep plants, two underground coal mines, and an underground lead mine. Preliminary results show that there is potential for overexposure to noise at these sites if workers spend a significant time in the noisy locations. Future surveys are planned, with an emphasis on underground coal and metal/nonmetal mining.

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

BIBLIOGRAPHY

Bauer ER, Kohler JL [2000]. Cross-sectional survey of noise exposure in the mining industry. In: Bockosh GR, Karmis M, Langton J, McCarter MK, Rowe B, eds. Proceedings of the 31st Annual Institute of Mining Health, Safety and Research. Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, pp. 17-31.

Bauer ER, Podobinski DJ, Reeves ER [2001]. Noise exposure in longwall mining and engineering controls research. In: Proceedings of Longwall USA International Exhibition & Conference. Overland Park, KS: Intertec Publishing Corp., pp. 51-69.



Prototype of inexpensive personal noise dosimeter.

A MODEL HEARING CONSERVATION PROGRAM FOR COAL MINERS

RESEARCHER: David C. Byrne

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

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

KEYWORDS: Noise, hearing conservation, hearing loss prevention

BIBLIOGRAPHY

Franks JR [1996]. Analysis of audiograms for a large cohort of noise-exposed miners. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Biomedical and Behavior Science.

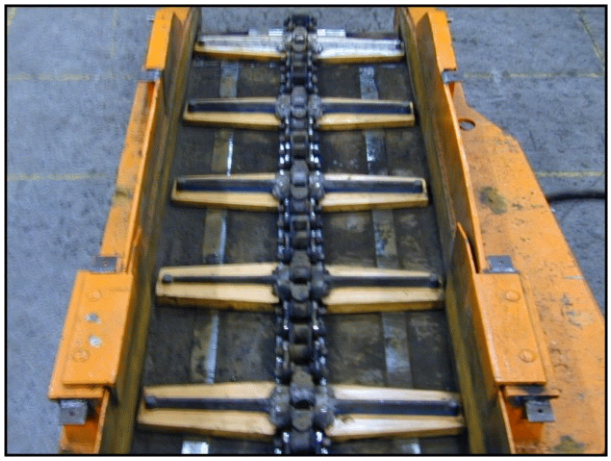
NIOSH [1998]. Criteria for a recommended standard: occupational noise exposure, revised criteria 1998. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-126.

RESEARCH SUMMARY: Hearing loss is 1 of the 21 priority research areas in the National Occupational Research Agenda and is a major occupational health problem for coal miners. The prevalence of noise-induced hearing loss (NIHL) has remained relatively unchanged for the last 20 years. A significant reason for this is the lack of a systematic plan of intervention proven to be effective for the mining community.

Together with researchers from The Pennsylvania State University, a multiyear 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, implement this program at a cooperating mine, evaluate the program over a 5-year period to demonstrate its efficacy in preventing hearing loss, and transfer the findings of this study to the coal mining industry (and others) as quickly and thoroughly as possible.

Other specific goals 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 a hearing handicap; identify the relationship between NIHL and hearing threshold shifts; determine the most effective hearing protection devices by measuring the amount of sound attenuation provided for each individual miner; and explore the practicality of using inexpensive personal noise monitors for alerting miners to the presence of excessive noise levels.

A detailed plan for each program element was completed, and data-bases were created to analyze audiometric test results, noise exposure measurements, and other information. Periodic hearing tests have been ongoing and will continue to be done every April and November for the duration of the project. During the third year, attention was focused on the evaluation of personal hearing protection and the development and testing of effective health education training materials and delivery methods. As this project begins its fourth year, more emphasis is to be placed on the investigation and evaluation of technological advances in personal noise monitoring equipment and alternative approaches to hearing loss prevention.



Coated flight bars on the continuous miner's conveyor system.

ENGINEERING CONTROLS FOR HEARING LOSS PREVENTION

RESEARCHER: Peter G. Kovalchik

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

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

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

Partnerships have been established with JOY Technology, Inc., Kennametal, Inc., Fletcher, Inc., and Consol Energy, Inc. These companies are helping to evaluate the strengths and weaknesses of various implementation strategies. The strategies form the basis of a long-term implementation plan where appropriate engineering controls are to be selected and targeted to reduce excessive noise exposures to workers.

This project is investigating continuous miners and roof bolters. The investigations have concluded that water will decrease the sound level of the continuous miner by at least 5 dB at the frequency range between 1,000 and 6,000 Hz. Other engineering controls on the continuous miner that show promise is the coating of flight bars on the continuous miner's conveyor system. These preliminary investigations show reduced noise levels. However, more investigations are needed for wear or abrasive verification. Wet drilling is also being looked at to see if it is a viable engineering noise control solution for roof bolting machines.

KEYWORDS: Noise, control technology, mining, equipment

BIBLIOGRAPHY

Bartholomae RC, Parker RP [1983]. Mining machinery noise control guidelines. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Handbook 2-83.

A mechanic removes sound absorption material from a motor to prepare for a noise measurement with an uncontrolled source.

DEFINITION AND ASSESSMENT OF ENGINEERING NOISE CONTROLS

RESEARCHER: **Efrem R. Reeves, Ph.D.**

AFFILIATION: **Pittsburgh Research Laboratory**
National Institute for
Occupational Safety and Health
(412) 386-6683

PURPOSE: Document and evaluate noise control technologies that are used in or applicable to the mining and construction industries and then expand this base of information to other industries. Acquire a better understanding of noise-generating mechanisms to help develop new noise control technology.

KEYWORDS: Noise, control technology, sound level, hearing conservation

RESEARCH SUMMARY: Noise-induced hearing loss is the most common occupational illness in the United States today. More than 30 million workers are exposed to excessive noise levels. Engineering control of noise is the long-term solution to the Nation's occupational hearing loss problem. However, in the mining industry the application of engineered noise controls has had many problems. An important step for the application of existing control technology or the development of new technology is to identify existing controls and their effectiveness.

Engineering noise control effectiveness is measured by acquiring acoustic data with and without the control in place. The measured acoustic parameters include sound pressure level, sound intensity level, and percent noise dose. If a control cannot be removed from an application, an effort is made to find a machine of similar make, model, and age without the treatment in place.

In addition to being used to evaluate the effectiveness of an engineering noise control, sound intensity measurements are applicable for noise source location. Once the primary noise sources are identified, engineering controls can be more effectively implemented.

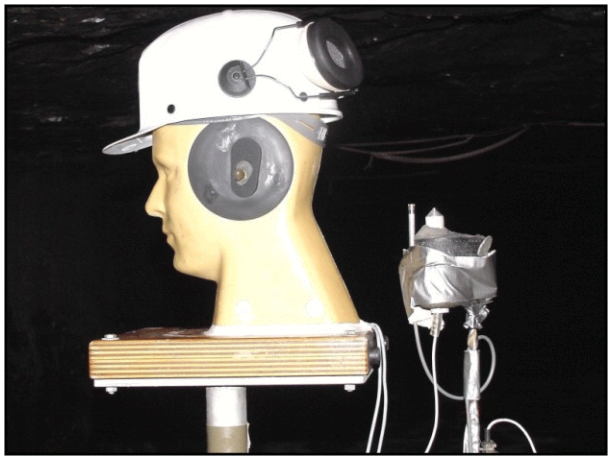
To date, extensive noise measurements have been made at a western U.S. underground gold mine. Several more visits are planned to various western underground gold mines in the near future.

BIBLIOGRAPHY

Bartholomae RC, Parker RP [1983]. Mining machinery noise control guidelines. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Handbook 2-83.

Franks JR [1996]. Analysis of audiograms for a large cohort of noise-exposed miners. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Biomedical and Behavior Science.

Rasmussen G [1989]. Intensity: its measurement and uses. Sound and vibration *23*(3):12-21.



Measurement of pressure wave in the Lake Lynn underground mine.

INVESTIGATION OF IMPULSE NOISE IN MINING

RESEARCHERS: Alex C. Smith and Michael J. Sapko

**AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683**

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

KEYWORDS: Mining, exposure, intense sounds, impulse noise

BIBLIOGRAPHY

Kuroda E, Kobayashi N [1982]. Studies on methods for measuring blast noise: part 2. J Ind Explosives Soc (Japan) *43*(4):233-238.

Kuroda E, Yoshida T, Ito S, Kobayashi N [1982]. Studies on methods for measuring blast noise: part 1. J Ind Explosives Soc (Japan) *43*(4):225-232.

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

Research continues to measure the pressure wave forms from the confined detonation of the Mine Safety and Health Administration-approved permissible "Rock Buster" in the Lake Lynn Laboratory underground mine. Pressure wave forms are evaluated with an audiometric model developed by Dr. G. Richard Price, U.S. Army, Aberdeen Proving Ground. Preliminary results show that the waveforms measured around one 90° bend can produce a serious hearing loss in an unprotected ear from one exposure to one waveform. In the 95% percentile ear, the model would predict a 40- to 50-dB permanent threshold shift, resulting in permanent hearing loss. Experimental results, verified by the model, also show that a worker detonating these devices from 200 feet away and around one 90° bend is protected by wearing a properly fitted hearing protection device, such as a plug or muff. Close collaboration with the U.S. Army Research Laboratory continues in FY02 with a focus on multiple-wave interactions within and around corners.

Controlled free-field noise measurements on an air-rotary drilling rig.

A HEALTH HAZARD STUDY OF SURFACE DRILLING OPERATIONS

RESEARCHERS: R. J. Matetic and David K. Ingram

**AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683**

KEYWORDS: Drilling, noise, silica dust

PURPOSE: Quantify health hazards (noise and dust) associated with the surface drilling industry. Develop appropriate engineering controls, recommend healthier and safer work practices, and examine the use of personal protective equipment to minimize or eliminate these hazards to workers.

RESEARCH SUMMARY: Past NIOSH research has concluded that short- and long-term exposure to excessive levels of noise can result in noise-induced hearing loss (NIHL). In addition, excessive levels of respirable silica dust can lead to silicosis. Occupational hearing loss is the most common job-related disease in the United States. NIHL is permanent and irreversible. NIOSH data indicate that at least 70% of mine workers engaged in drilling activities suffer NIHL severe enough to be classified as a hearing disability. Previous studies by the Mine Safety and Health Administration have shown that silica dust levels exceed the permissible exposure level for surface mine drillers 75% of the time during which they are performing drilling operations. These same noise and dust hazards exist at all surface drilling operations.

Currently, this National Occupational Research Agenda project is investigating noise and dust exposures at various locations on many types of surface drilling equipment to quantify the extent of the health hazards and to develop techniques or solutions to reduce their effects. Results from 14 field sites in 6 States on 6 different drill rigs have shown that surface drilling operations are generating excessive noise levels and, in some cases, excessive dust levels. Each field investigation provided free-field noise measurements, A-weighted sound pressure profiles, and personal noise dosimeter data (along with personal dust monitoring data), all supplemented with a time motion study. These field data are being reported to the drilling industry via national and State annual drilling association conferences. Furthermore, a cooperative agreement with the second largest manufacturer of drilling equipment has been established to investigate engineering control strategies to reduce hazardous noise and dust output during drilling operations. Recent lab and controlled field testing has identified several noise sources on drilling equipment that can be targeted for engineering control designs. Ultimately, this project will specify the health hazards of surface drilling operations and provide tools and techniques to improve workers' exposures to these hazards.

BIBLIOGRAPHY

Tomb TF, Gero AJ, Kogut J [1995]. Analysis of quartz exposure data obtained from underground and surface coal mining operations. Appl Occup Env Hyg *10*(12):1019-1026.

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

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

RESEARCHER: **Charles Vaught, Ph.D.**

AFFILIATION: **Pittsburgh Research Laboratory**
National Institute for
Occupational Safety and Health
(412) 386-6683

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

RESEARCH SUMMARY: Following a study of 17,260 audiograms from 2,871 coal miners, NIOSH concluded that 90% of coal miners have a hearing impairment by age 51, compared with only 10% of the general population. Current hearing conservation research, done in collaboration with the Health Effects Laboratory Division and Michigan State University, is investigating two strategies designed to increase hearing loss prevention behaviors among coal miners. A communication framework for studying emotion in behavior change, the Extended Parallel Processing Model, has been developed and validated in several occupational settings. It is being used to assess the comparative effectiveness of humor versus fear in motivating coal miners to adopt hearing loss prevention behaviors.

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

KEYWORDS: Mining, hearing loss, communication research

BIBLIOGRAPHY

Witte K [1993]. Message and conceptual confounds in fear appeals: the role of judgment methods. South Comm J *58*:147-155.

Witte K [1994]. Fear control and danger control: an empirical test of the extended parallel process model. Communication Monographs *61*:113-134.

Witte K, Morrison K [1995]. The use of scare tactics in AIDS prevention: the case of juvenile detention and high school youth. J Appl Comm Res *23*:128-142.

Wind tunnel used to evaluate shield dust entrainment.

DUST MEASUREMENT AND CONTROL

DUST CONTROL FOR LONGWALL MINING

RESEARCHER: Jay F. Colinet

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

KEYWORDS: Coal mine dust, underground mining, control technology

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

RESEARCH SUMMARY: Medical studies have shown that long-term exposure to excessive levels of respirable coal mine dust can lead to 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 shows that about 8% of the workers with 25 or more years of mining experience were diagnosed with CWP. As of 1999, shift production from longwall mining operations averaged 5,000 tons per shift. Longwall mines accounted for over 50% of underground coal production. Nearly one of every five compliance dust samples from longwall operations exceeded the permissible exposure limit. Data from dust sampling, medical screening, and production trends show that controlling dust on longwalls remains a major health concern and challenge for longwall mining.

This project addresses improvements in the application of primary control technologies: ventilating air and spray water. Testing is being done at NIOSH's full-scale longwall gallery to evaluate the interactions between ventilating air, water flow, water pressure, spray system design, cutting direction, and mining height to measure the impact on dust levels on the longwall face. Tests at a mining height of 7 feet show that increases in airflow, spray system design, and spray operating pressure had the greatest impact on shearer operator dust levels. More testing is being done at a mining height of 9 feet. Tests were also done within a wind tunnel designed to simulate dust liberation during shield advance to quantify dust entrainment in airstreams of increasing velocity. Statistically significant increases in respirable and total dust levels were observed as air velocity was increased from 400 to 1,600 feet per minute. Testing is continuing to evaluate the impact of dust composition and/or moisture content on entrainment levels.

BIBLIOGRAPHY

Listak JM, Chekan GJ, Colinet JF [2001]. Laboratory evaluation of shield dust entrainment in high-velocity airstreams. SME preprint 01-144. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.

Rider JP, Colinet JF [2001]. Reducing worker exposure to dust generated during longwall mining. In: Proceedings of the Seventh International Mine Ventilation Congress (Krakow, Poland), pp. 275-282.

Rider JP, Colinet JF, Prokop AE [2001]. Impact of control parameters on shearer-generated dust levels. SME preprint 01-184. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.

The model of the one-piece personal dust monitor *(right)* may replace both the cap lamp battery and dust sampling filter *(left)* for an overall reduction in weight and volume carried by the miner.

ASSESSMENT OF PERSONAL PARTICULATE EXPOSURE

RESEARCHER: Jon C. Volkwein

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

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

PURPOSE: Develop person-wearable dust monitors.

RESEARCH SUMMARY: Prolonged inhalation of respirable coal mine dust can cause coal worker's pneumoconiosis (CWP). During 1968-90, CWP caused the death of 55,467 U.S. coal miners. In 1988, NIOSH recommended that diesel exhaust be regarded as a potential occupational carcinogen. The American Conference of Governmental Industrial Hygienists recently recommended a diesel particulate threshold limit value of 50 $\mu g/m^3$.

The sampling of coal mine dust has remained virtually unchanged for the last 30 years. The instrument used to determine personal compliance with this standard is the coal mine dust personal sampler unit. It consists of a size classification device, a filter, and an air pump. The unit has remained the same because of the simplicity of design and the ability to sample directly for dust mass. However, there are drawbacks. Sampling is at infrequent intervals, and the results are not provided soon enough for timely correction of overexposure. New types of coal mine dust sampling devices to measure dust and diesel particulate are required. To fill these needs, NIOSH is developing various devices to meet different sampling requirements.

Under contract, NIOSH is developing a highly accurate person-wearable dust monitor using the tapered-element operating microbalance (TEOM) principle. The TEOM is the heart of a dust monitor used commercially to assess combustion particulate and ambient air quality levels.

A new, low-cost instrument is using differential pressure as a surrogate for mass. This device uses a disposable sample tube and a small pump to deposit mass onto a filter. Dust levels are denoted by an increase in pressure.

New commercial instruments and new combinations of technologies are being evaluated. This includes a combination of size-selective sampling and differential pressure measurement. This could be the basis for a novel, near-real-time diesel particulate monitor for mine use.

Smoke detector technology is being integrated with light-scattering technology to discriminate between coal mine dust and diesel particulate. The combined detector/light-scattering approach uses ion trap technology and discrete forward light scattering to determine diesel and dust levels, respectively.

Much of this work is being done in partnership with industry and academia. This research is expected to result in several new tools and approaches to particulate measuring in mining.

BIBLIOGRAPHY

Cantrell BK, Volkwein JC [2001]. Mine aerosol measurement. In: Willeke K, Baron PA, eds. Aerosol measurement: principles, techniques, and applications. New York, NY: John Wiley & Sons, Inc.

Ramani RV, Mutmansky JM, Honglin H, Volkwein JC, Marple VA, Olson BA, et al. [2001]. A comparative evaluation of the differential-pressure-based respirable dust dosimeter with the personal gravimetric respirable dust sampler in underground coal mines. In: Proceedings of the Seventh International Mine Ventilation Congress (Krakow, Poland), pp. 243-251.

Volkwein JC, Thimons ED [2001]. New tools to monitor personal exposure to respirable coal mine dust. In: Proceedings of the Seventh International Mine Ventilation Congress (Krakow, Poland), pp. 143-150.

Preparing to sample dust generated by a surface drill.

DUST CONTROL IN SURFACE COAL MINING

RESEARCHER: Jeffrey M. Listak

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

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

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

The interactions between drilling parameters and overburden lithology will be characterized to determine how these interactions affect respirable silica dust generation. A new sampling method was developed and tested for silica dust monitoring of surface mine rotary drill rigs and surveys at field sites have begun. Once the drilling parameters and rock characteristics have been defined in terms of their impact on silica dust generation, appropriate control technologies can be developed to reduce silica emissions. Furthermore, many surface drills have dust containment problems at the shrouded drill table over the hole. Full-scale testing of a prototype inlet hood for the drill's primary dust collection system is being done for respirable dust capture at various parametric conditions. Comparative tests with the traditional inlet configuration will be performed. During surface mine dust surveys, sampling was also done to identify silica sources, exposures, and controls for bulldozer operators. Finally, investigations into improving quality control methods to ensure the integrity of enclosed environmental cabs on surface mining equipment are being done through cooperative work with mining companies, equipment manufacturers, and the Mine Safety and Health Administration. A Cooperative Research and Development Agreement was drafted with Clean Air Filter, Defiance, IA, to develop field test methods for evaluating the environmental integrity of enclosed operator cabs.

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

BIBLIOGRAPHY

NIOSH [2001]. Technology news 485: Improved cab air inlet location reduces dust levels and air filter loading rates. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

NIOSH [2001]. Technology news 487: Sweeping compound application reduces dust from soiled floors within enclosed operator cabs. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

Haul truck dumping at a crusher in an underground limestone mine.

SILICA DUST CONTROL IN METAL/ NONMETAL MINING

RESEARCHERS: **Andrew B. Cecala and Gregory J. Chekan**

AFFILIATION: **Pittsburgh Research Laboratory National Institute for Occupational Safety and Health (412) 386-6683**

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

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

RESEARCH SUMMARY: Although all types of respirable dust can harm a worker's lungs, overexposure to respirable silica is extremely hazardous. Chronic overexposure to respirable crystalline silica (particle diameter < 10 microns) leads to progressive lung deterioration known as silicosis. In addition, the International Agency for Research on Cancer has stated that silica dust is carcinogenic (lungs). Records of the Mine Safety and Health Administration (MSHA) show that there is a significant percentage of both underground and surface metal/nonmetal miners overexposed to silica each year. The following occupations have the highest exposures: truck drivers, crusher operators, front-end loader operators, rotary drill operators, bag operators, bag stackers, laborers, maintenance, cleanup, and utility workers.

An extensive effort is ongoing to lower equipment operators' dust exposure by improving filtration efficiency and pressurization in enclosed cabs in all types of mining equipment. This research is being done jointly by the Pittsburgh Research Laboratory and the Engineering and Physical Hazards Branch (Cincinnati) in cooperation with MSHA, a number of mining companies, and several dust filtration and pressurization manufacturers. Evaluations are being done at several different surface mining operations on rotary drilling machines. An enclosed cab study is also being evaluated on a haul truck at an underground limestone mine.

Research is being done at underground limestone and gold mines to determine primary silica dust sources and evaluate control technology. Improvements in mine-wide ventilation and localized ventilation systems are being investigated as a primary means for controlling various dust sources in limestone mines. In gold mines, roadheading machines can generate high dust levels. Research has begun to quantify dust generation levels and sources before evaluating controls.

Another effort is a cooperative study with a silica sand operation to investigate the potential for improving clothes-cleaning capabilities in an enclosed booth environment. Several different possibilities are being examined to provide for the best cleaning potential in the shortest time period.

BIBLIOGRAPHY

Cecala AB, Organiscak JA, Heitbrink BA [2001]. Dust underfoot: enclosed cab floor heaters can significantly increase operator's respirable dust exposure. Rock Prod *104*(4):39-44.

NIOSH [2001]. Hazard controls: dust protection for bag stackers. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, HC31, DHHS (NIOSH) Publication No. 2001-142.

NIOSH [2001]. Technology news 486: Floor heaters can increase operator's dust exposure in enclosed cabs. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

Emptying a dust collector box on a roof bolter.

CONTROL OF SILICA DUST EXPOSURES IN UNDERGROUND COAL MINING

RESEARCHER: Gerrit V. R. Goodman, Ph.D.

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

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

RESEARCH SUMMARY: In-mine surveys suggest that overexposures to respirable silica dust can occur when the roof bolter works downwind of the mining machine. A canopy air curtain, mounted on the underside of the roof bolter operator's canopy, was evaluated and shown to reduce these exposures by providing a constant flow of filtered air over the breathing zone of the bolter operator. However, its size could detract from its usefulness in lower seam operations. To provide more headroom under the canopy, an air tube was tested for its ability to control respirable dust levels. Results showed that this device provided dust reductions for positions close to the air tube, but was more adversely affected by higher mean entry air velocities than the canopy air curtain. However, the air tube offers certain advantages, including a smaller profile that requires less headroom beneath the operator's canopy. It is also more effective at lower air flows than the canopy air curtain and uses a smaller fan that costs less, while producing less heat and noise. A roof bolter manufacturer recently revealed that the main hydraulic circuit on the bolter could be used to power the system fan. Consequently, in-mine evaluations of the canopy air curtain and air tube are planned.

Roof bolter operators can also expose themselves to high levels of respirable dust when removing drill cuttings from the dust collector on the bolter. Two methods of cleaning the dust collector are being evaluated: using a wooden wedge to scrape dust from the box, and inserting a rigid box or flexible bag into the largest compartment of the dust collector to collect the dust. The wedge is a very common, but unacceptable method that is used to scrape dust from the box onto the mine floor. Preliminary testing shows that high dust levels can be generated when cleaning the collector with the wedge, and considerable dust can also be deposited on the clothes of the bolter operator. The other method allows the collector dust to be loaded into the rigid box or flexible bag, which is then be removed so that the dust is dumped against the rib in a controlled manner. The rigid box/flexible bag method seems to reduce airborne dust levels and clothes contamination.

KEYWORDS: Silica exposures, dust, coal mining, ventilation

BIBLIOGRAPHY

Goodman GVR, Organiscak JA [2001]. Laboratory evaluation of a canopy air curtain for controlling occupational exposures of roof bolters. In: Proceedings of the Seventh International Mine Ventilation Congress (Krakow, Poland), pp. 299-305.

Goodman GVR, Listak JM, Organiscak JA [2000]. Occupational silica dust exposures and their control on continuous mining operations. In: Bockosh GR, Karmis M, Langton J, McCarter MK, Rowe B, eds. Proceedings of the 31st Annual Institute of Mining Health, Safety and Research. Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, pp. 105-114.

Water-powered scrubber testing to improve air movement and dust capture.

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

RESEARCHER: John A. Organiscak

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

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

RESEARCH SUMMARY: Overexposure to airborne respirable crystalline silica dust can cause serious or fatal respiratory disease. Mining machine operators were the most frequent occupation (16.0%) recorded on silicosis-related death certificates during 1991-92. Coal mining was the first (9.5%) and metal mining was the third (8.6%) most frequently associated industry. Mine Safety and Health Administration (MSHA) compliance data for permissible exposure limits (PELs) show that a significant portion of the airborne respirable dust samples collected in the mines exceed the mandated 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 PELs. These data show that there continues to be a high likelihood of overexposure to silica dust in the mining industry, especially in coal and metal mines, which have a high incidence of silicosis deaths.

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

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

Water droplet size distributions and velocities for various spray nozzle types are being measured by a phase Doppler particle analyzer at Carnegie Mellon University's Spray Technology Center. NIOSH researchers are studying water spray(s) operating parameters for air inducement characteristics in a tube. Multiple in-series spray arrangements along the tube are being investigated to determine optimal design characteristics for a small high-efficiency water-powered scrubber.

CHARACTERIZATION OF VISUAL DUST PLUMES FROM HIGHWALL DRILLS AT SURFACE COAL MINES

RESEARCHER: Joseph C. Cocalis

AFFILIATION: Division of Respiratory Disease Studies
National Institute for Occupational Safety and Health
(304) 285-5711

KEYWORDS: Surface coal mine highwall drill, visible dust, respirable dust, respirable crystalline silica, particle size distribution, submicrometer particulate

BIBLIOGRAPHY

30 CFR 72, Health Standards for Abrasive Blasting and Drill Dust Control; Surface Coal Mines and Surface Work Areas of Underground Coal Mines.

PURPOSE: To characterize visible mineral dust plumes from highwall drilling operations at surface coal mines. Characterization includes an assessment of the respirable dust concentrations, particle size distributions, and respirable crystalline silica content.

RESEARCH SUMMARY: Although visible dust plumes indicate possible silica dust overexposure to drill operators, the extent of overexposure is not known. To evaluate this, surveys were done at about 21 surface coal mines throughout the 11 Mine Safety and Health Administration coal mine health districts. This project characterized visible dust plume exposures that occurred as a result of poor highwall drilling work practices. Since visible dust plumes do not occur when controls are working properly and when proper work procedures are followed, it was necessary to simulate poor work practices (with safeguards in place). For example, miners imitated improper use of the dust control shroud, while at the same time precautions were taken to ensure that both miners and investigators were not overexposed to respirable dust containing quartz and/or respirable crystalline silica. Preliminary findings indicate that where there is visible dust there is respirable dust, that short-term, high-intensity respirable crystalline silica exposures are possible when visible plumes are present, that the percent silica can vary as a highwall drill is moved to various locations within a mine, and that some cab filtration systems were ineffective under certain conditions.

Zero emission utility solution (ZEUS) vehicle, an internal combustion vehicle that operates on hydrogen.

DIESEL EMISSIONS

REDUCING DIESEL PARTICULATE EXPOSURE IN WESTERN MINES

RESEARCHERS: Ron Backer, Dave Denton, Chelsea Woodward, and Richard Miller

AFFILIATION: Spokane Research Laboratory
National Institute for Occupational Safety and Health
(509) 354-8000

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

BIBLIOGRAPHY

Woodward C [2001]. Internal combustion mine vehicle: an intermediate step for hydrogen fuel use. Presentation at Canadian Hydrogen Association conference, Victoria, British Columbia, Canada, June 17-20.

PURPOSE: Reduce the exposure of workers in western mines to potentially dangerous exhaust emissions 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. The Mine Safety and Health Administration (MSHA) has identified DPM as a potential hazard, and a new rule governing the emission of DPM in underground metal and nonmetal mines took effect July 5, 2001. Research includes evaluating diesel exhaust after treatment; developing real-time methods for measuring ambient DPM; evaluating diesel fuel substitutes such as hydrogen, water emulsions, and biodiesels; and investigating new technologies that can mitigate DPM levels in underground mines. A hydrogen-powered internal combustion mine truck, ZEUS (zero emissions utility solution), is being used as a test vehicle to prove this technology as a feasible alternative to fossil fuel. Cooperators include mine operators, equipment suppliers and manufacturers, NIOSH, and MSHA.

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

Researchers analyze workplace samples for diesel exhaust particulate using NIOSH Method 5040 for Diesel Exhaust (Elemental Carbon).

DIESEL ENGINE EMISSIONS MEASUREMENT AND ANALYSIS

RESEARCHERS: James D. Noll, Ph.D. and J. Emery Chilton, Ph.D.

AFFILIATION: Pittsburgh Research Laboratory
National Institute for Occupational Safety and Health
(412) 386-6683

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

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

The analytical procedure recommended by the Mining Safety and Health Administration in its final rule governing exposure of underground workers to DPM is to use the instrumentation and techniques of NIOSH Method 5040, which provides the carbon content (organic, elemental, and other forms of carbon, such as carbonates) of the dust collected on a filter sample. This project directly addresses the issue of accurately measuring DPM in the presence of carbon-containing mine aerosols (coal, limestone, and other ore dusts), oil mists, and cigarette smoke. Although a size-selective sampler is used to restrict the filter deposit to primarily DPM particles, which are finer than mine dusts, it is uncertain whether this is sufficient. NIOSH performs lab and field experiments to define and mitigate the effects of nondiesel dusts on the measurement of DPM.

In underground mines with airborne ore dusts and elevated DPM levels, ore samples are being gathered. Thus far, two mines have been visited; one contains bitumen, the other a graphitic ore. Size distributions of workplace dusts have been obtained and host rock samples have been pulverized to a size distribution that represents that of the mine. The samples are mixed with diesel exhaust and injected into a lab chamber. Dust samples are collected from within the chamber, and the results are analyzed. The goal is to quantify the effects of the carbon-based dusts on the compliance method and, ideally, to develop methods to stop these effects.

Another recent development being investigated is the use of a second quartz filter behind the first to serve as a means to partially mitigate the oversampling of organic vapor by quartz and to pick up spurious contamination from organic vapor of nondiesel origin. The organic carbon on the second filter is subtracted from that on the first.

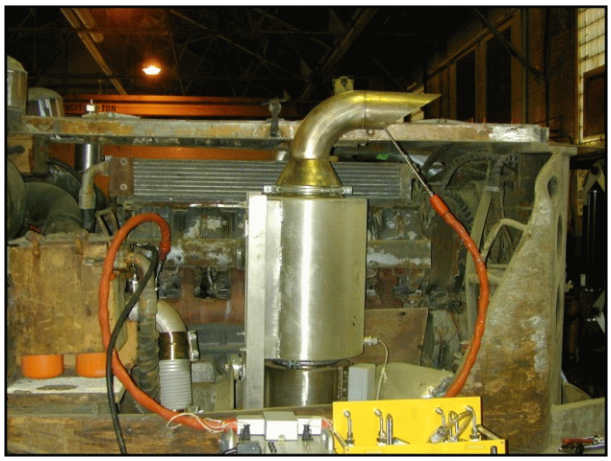
Accurate DPM measurement can reduce uncertainties about workplace concentrations of DPM, which enables better assessment of the effects of control technology on tailpipe emissions.

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

BIBLIOGRAPHY

Cantrell BK, Watts WF Jr. [1997]. Diesel exhaust aerosol: review of occupational exposure. Appl Occup Env Hyg *12*(12):1019-1027.

McDonald JF, Cantrell BK, Watts WF Jr., Bickel KL [1997]. Evaluation of a soybean oil based diesel fuel in an underground gold mine. CIM Bull *90*(1015): 91-95.



Diesel exhaust upstream and downstream of a particulate matter filter is sampled to determine filtration efficiency for solid carbon core particles (diesel soot).

SELECTING AND EVALUATING DIESEL EMISSION CONTROLS ON MINE EQUIPMENT

RESEARCHERS: George H. Schnakenberg, Jr., Ph.D. and Aleksandar Bugarski, Ph.D.

AFFILIATION: Pittsburgh Research Laboratory National Institute for Occupational Safety and Health (412) 386-6683

PURPOSE: Investigate and evaluate performance of exhaust measurement methods and diesel exhaust control technology for application in underground coal and metal/nonmetal mines.

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

BIBLIOGRAPHY

Schnakenberg GH Jr. [2001]. Estimate of technically feasible DPM levels for underground metal and nonmetal mines. Min Eng *53*(9):45-51.

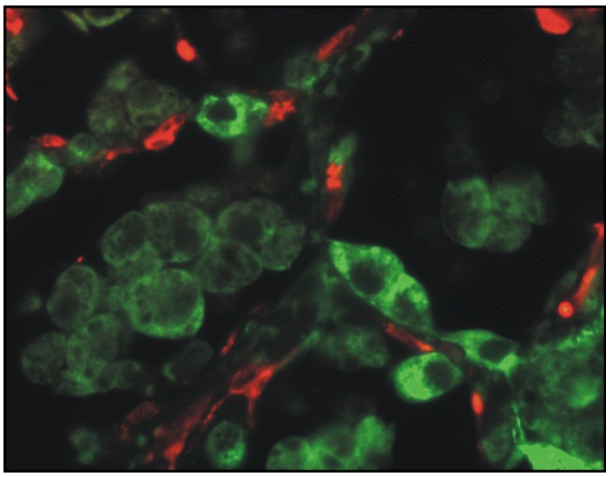
RESEARCH SUMMARY: The Bituminous Coal Operators Association, the United Mine Workers of America, and NIOSH formed a partnership to address the means to control diesel emissions and to comply with the Mine Safety and Health Administration coal diesel rule that was promulgated in January 2001. The goal of this alliance is to find and test practical methods to reduce diesel exhaust contaminants. Concerns, which formerly focused on outby light-duty vehicles, are now shifting to outby heavy-duty and permissible inby vehicles.

Control technology, predominantly hot filters, is currently commercially available to the mining market. This project addresses the suitability of these filters for underground coal mine use (i.e., how well do they filter, can they spontaneously burn off collected soot, do they affect concentration of CO and NO_2?).

Extensive testing of filters and other technology is to be done on the bench at The Pennsylvania State University and at Lake Lynn Laboratory using a transportable engine dynamometer now under construction. The dynamometer will be capable of handling both light- and heavy-duty coal mine engines. Testing at Lake Lynn allows the first real-world controlled-condition testing, where exhaust dilutions and other factors are closer to real-mine situations. Particulate matter in tailpipe, partial flow dilution tunnel, and mine entry dilution will be measured. Effects of control technology, such as filters, fuel sulfur, water-fuel emulsions, etc., on the particulate emissions and the regulated gases emissions are to be assessed. With this dynamometer, it is also possible to measure other effects, such as engine derating and modified loadings at high-elevation mines in Utah.

Another activity has been to try various methods to determine in-use exhaust filter performance. To that end, several in-use filters have been tested in a U.S. and in Canadian mines.

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



Photomicrograph of the alveolus of a rat exposed to silica dust and then to the CYP1a1-inducer, NF.

OCCUPATIONAL ILLNESS AND HEALTH HAZARDS

PARTICLE-INDUCED LUNG INJURY IN MIXED EXPOSURES

RESEARCHER: Ann F. Hubbs, D.V.M., Ph.D.

AFFILIATION: Health Effects Laboratory Division
National Institute for
Occupational Safety and Health
(304) 285-6032

KEYWORDS: Mixed exposures, lung cancer, pneumoconiosis

PURPOSE: Epidemiology studies suggest that coal miners, most of whom are smokers, are greatly exposed to respirable particles, such as coal dust and silica dust, but are not at increased risk of getting lung cancer. Rats exposed to high doses of some, but not all, respirable particles develop lung cancer. While some interpret this to mean that mechanisms leading to lung cancer differ in rats and humans, the rodent exposures are largely exposures to single agents, whereas the human exposures are mixed exposures.

These studies aim to clarify how silica and coal dust influence the metabolism of chemicals that cause cancer in humans and lab animals so that animal studies can be more accurately extrapolated to miners.

RESEARCH SUMMARY: Major cancer-causing agents in cigarette smoke do not actually cause cancer until they are metabolized by an enzyme system in the body called cytochrome P450 (CYP). CYP comes in many different forms. One of the most important of these is CYP1A1, the system that changes the polycyclic aromatic hydrocarbons (PAHs) in cigarette smoke into cancer-causing agents. An important trait of CYP1A1 is that the compounds it metabolizes can actually induce the activity of CYP1A1 manyfold. This greatly increases the actual carcinogen dose from inhaled cigarette smoke.

Researchers are investigating whether the dusts of coal mines are truly independent of the carcinogens in cigarette smoke. It was found that in lab animals, the dusts in coal mines actually change CYP1A1 and thus the expected carcinogen dose from cigarette smoke. Several dusts present in coal mines—coal dust, iron oxide, and silica—each alter the induction of CYP1A1. However, the response (increasing or decreasing) differs with each dust. Thus, each of these dusts is an apparent modifier of the cancer-causing ability of cigarette smoke. This means that animal experiments on dusts alone may be comparable to human epidemiology studies of nonsmoking miners, but not to those of smoking miners.

Using techniques developed in the lab, researchers are investigating whether expression of CYP1A1 is also changed by dust exposure in the lungs of autopsied coal miners. The goal is a better understanding of the cancer risks of miners and other workers in the dusty trades.

BIBLIOGRAPHY

Albrecht C, Adolf B, Weishaupt C, Hohr D, Zeittrager I, Frieman J, et al. [2001]. Clara-cell hyperplasia after quartz and coal-dust instillation in rat lung. Inhal Toxicol *13*:191-205.

Battelli LA, Hubbs AF, Ma JYC, Kashon ML, Castranova V [2001]. Quantifying cellular expression of cytochrome P4501A1 (CYP1A1) in the pulmonary alveolus: a comparison of indirect enzymatic immunohistochemistry (IH) and indirect immunofluorescence (IF). Toxicologist *60*:403.

Battelli LA, Hubbs AF, Simoskevitz RD, Vallyathan V, Bowman L, Miles PR [1999]. Cytochrome P450 1A1 and 2B1 in the rat lung: exposure to silica and inducers of xenobiotic metabolism. Toxicol Sci *48*:97.

EFFECTS OF DUSTS ON ASTHMA AND PULMONARY INFECTIVITY

RESEARCHER: Vincent Castranova, Ph.D.

AFFILIATION: Health Effects Laboratory Division
National Institute for Occupational Safety and Health
(304) 285-6056

KEYWORDS: Mixed exposures, chronic pulmonary obstructive disease, pulmonary infections, diesel exhaust particles

BIBLIOGRAPHY

Castranova V, Ma JYC, Yang H-M, Antonini JM, Butterworth L, Barger MW, et al. [2001]. Effect of exposure to diesel exhaust on the susceptibility of the lung to infection. Env Health Perspec *109*(Suppl 4):609-612.

Yang HM, Antonini JM, Barger MW, Butterworth L, Roberts JR, Ma JKH, et al. [2001]. Diesel exhaust particles suppress macrophage function and slow the pulmonary clearance of Listeria monocytogenes in rats. Env Health Perspec *109*:515-521.

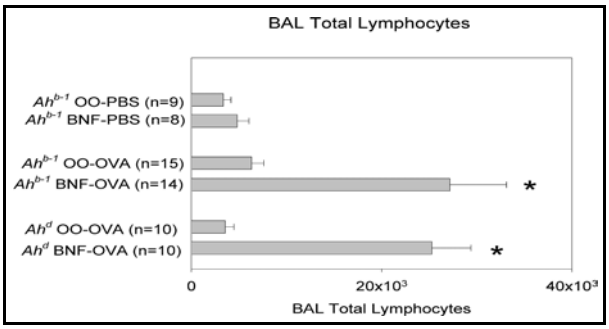
Yang HM, Barger M, Castranova V, Ma JKH, Yang J-J, Ma JYC [1999]. Effect of diesel exhaust particles (DEP), carbon black, and silica on macrophage response to lipopolysacchride: evidence of DEP suppression of macrophage activity. J Toxicol Env Health Part A *58*:261-278.

PURPOSE: Determine the effects of diesel exhaust particles on asthma and the ability of the lung to fight infections.

RESEARCH SUMMARY: NIOSH and the Mine Safety and Health Administration are concerned that exposure of underground miners to diesel exhaust particulate (DEP) could be a health risk. In addition, breathing DEP is considered a mixed exposure because DEP contains a mixture of chemicals that include a solid carbon core (soot), plus other toxic organic substances absorbed on the surface of the core. For this reason, research into possible adverse lung responses to breathing DEP is a National Occupational Research Agenda (NORA) priority and is vital. This project is evaluating the effects of DEP on the lungs to fight infection by testing the ability of alveolar macrophages (AMs) to engulf and kill bacteria. AMs are white blood cells in the lungs that "eat" and destroy foreign material, such as bacteria, that may have been breathed into the lungs.

This project involves studies in cells, lab animals, and human subjects. In the cell studies, AMs taken from the lungs of laboratory rats have been treated in petri dishes with DEP, the solid core of DEP, or the organic chemicals that have been removed from the core. DEP decreases the ability of AMs to engulf bacteria and reduces the reactive substances produced by AMs that are needed to kill bacteria. The ability of DEP to alter AM function seems to be due to the organic chemicals absorbed on the solid core of the DEP. DEP directly administered to rat lungs also depresses AM function. As a result, rat lungs treated with DEP are less able to kill bacteria, which causes the infection to increase and spread to other parts of the body. It is then possible that workers exposed to high DEP levels may be more susceptible to lung infections.

To study this finding in humans (in collaboration with the U.S. Department of Defense), mechanics who work on diesel-powered vehicles at Fort Lewis, WA, were given a questionnaire. They were asked questions about the seriousness and frequency of symptoms related to asthma and lung infections. Sampling the nasal linings of these workers has also been done to determine the presence of disease and inflammation after exposure to DEP. The results are now being analyzed.



Lymphocytic lung inflammation induced by exposure of mice with normal aryl hydrocarbon receptor function (*Ah*$^{b-1}$) or reduced function (*Ah*^{d}) to intraperitoneal olive oil (OO) or BNF in olive oil (BNF) and aerosolized phosphate-buffered saline (PBS) or ovalbumin in PBS (OVA). Bronchoalveolar lavage (BAL) was done after exposures, and total numbers of lymphocytes recovered by BAL are shown on the horizontal axis.

ENVIRONMENTAL CAUSATION OF ALLERGIES AND ASTHMA

RESEARCHERS: David N. Weissman, M.D., and Paul D. Siegel, Ph.D., Daniel M. Lewis, Ph.D., and Vincent Castranova, Ph.D.

AFFILIATION: Health Effects Laboratory Division National Institute for Occupational Safety and Health (304) 285-5720

KEYWORDS: Mixed exposures, chronic pulmonary obstructive disease, infectious disease

BIBLIOGRAPHY

Weissman DN, Siegel PD, Zhuang ZZ, Lewis DM [2001]. Augmentation of inflammatory and immune responses to inhaled antigen by combined exposure to beta-naphthoflavone (BNF) [Abstract]. J Allergy Clin Immunol *107*:S146.

PURPOSE: The National Occupational Research Agenda states that "workers are commonly exposed to combinations of chemicals or physical agents, but knowledge about the potential effects of mixed exposures is limited." Examples of mixtures cited include welding fumes, diesel exhaust particulate (DEP), and irritants such as metals on dust particles. As many as 1 million U.S. workers in the construction, transportation, mining, and other industries are estimated to have at least part-time exposure to DEP. Researchers hypothesize that inhalation exposure to chemicals called polycyclic aromatic hydrocarbons (PAH) alters lung immunity. PAH are found in airborne emissions from diesel engines and other combustion processes. Changes in lung immunity could predispose exposed people to allergies, airways obstruction, and respiratory infections. Researchers also believe that PAH affect lung immunity by binding to a receptor on cells called the aryl hydrocarbon receptor (Ahr).

RESEARCH SUMMARY: Combined exposures to a PAH (beta naphthoflavone (BNF)) and an allergen (ovalbumin (OVA)) in mice were carried out. Both mice with functional Ahr (*Ah*$^{b-1}$) and mice bred to have poorly functional Ahr (*Ah*^{d}) were used. Data show that exposure to BNF increases inflammatory and immune responses induced by inhaling OVA. However, this effect does not seem to require binding to the Ahr.

Nasal scraping samples from persons exposed to diesel exhaust and nonexposed controls were obtained. These are now being analyzed. Results will yield information on lung reactions to mixed dusts and will be useful for risk assessment.

GENETIC FACTORS FOR SILICOSIS AND LUNG CANCER IN GOLD MINERS

RESEARCHERS: Ainsley Weston, Ph.D., and Leslie T. Stayner, Ph.D.

AFFILIATION: Health Effects Laboratory Division, and Education and Information Division
National Institute for Occupational Safety and Health
(304) 285-6060

KEYWORDS: Genetics, risk assessment, silicosis

PURPOSE: Examine the relationship between genetic markers and occupational exposures to silica and asbestos in lung cancer, mesothelioma, and silicosis. Genetic changes that occur with the disease may give clues about past exposures, as well as prognosis and genetic variations in the inherited genes that may cause different people to react differently to similar exposures. The outcome of this project will yield important information on mechanisms of occupational cancer and silicosis.

RESEARCH SUMMARY: Lung tissue samples that were obtained as part of a workers compensation autopsy program are stored in an archive by collaborators at the National Center for Occupational Health, Johannesburg, Republic of South Africa. Samples are identified and obtained for both cases of disease and controls (from people who died with healthy lungs). A study was done that establishes the feasibility of isolating the DNA and determining the genetic markers from the South African lung tissue samples.

Initially, the sample numbers for these experiments are small because they are designed to come up with the logistics of sampling the archival samples in South Africa, bringing the samples to Morgantown, WV, and determining if the samples contained sufficient DNA for this study. Researchers have chosen to amplify two genes, *GSTT1* and *GSTM1*, which code for glutathione S-transferases, the enzymes that detoxify certain chemicals known to cause cancer. This gene is absent in some people; thus, these people may be more sensitive to certain chemical exposures. Initial studies identified that, of 167 samples, 147 were analyzable for *GSTM1* and 136 for *GSTT1*. Further, crude statistical analysis showed that people lacking *GSTM1* were at almost three times greater risk of lung cancer. People without *GSTT1* had nearly seven times greater risk of mesothelioma. No associations were found for silicosis. Based on these preliminary data, researchers have designed confirmatory studies.

Filter samples are analyzed for lead using field-portable anodic stripping voltammetry.

PORTABLE MONITORS FOR AIRBORNE METALS AT MINING SITES

RESEARCHER: Pamela L. Drake

AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000

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

RESEARCH SUMMARY: Most workers at mining and construction sites encounter dust and fumes throughout the workday. In some cases, metals and trace amounts of other toxic substances in these dusts and fumes can cause adverse health effects if exposures are great enough. Identifying toxic substances such as metals in airborne dust is a goal for all mining commodities.

KEYWORDS: Mining, exposure assessment, airborne contaminants

Presently, the most common methods for assessing workers' exposures to airborne metals involve collecting filter samples and sending them to an analytical laboratory, where wet chemistry methods are used for sample preparation and analysis. While these methods are very accurate, they tend to be costly, and the time delay from sample collection to analytical result is often at least several weeks, by which time the worker may have moved on to a different task or location. Field-portable instruments designed to measure airborne metal concentrations are cost effective and can help identify tasks or locations of excessive airborne metal exposures with end-of-shift speed. Such immediate results can facilitate the rapid evaluation of control strategies. NIOSH researchers are characterizing and testing such cost-effective, on-site screening methods.

Airborne lead was measured at milling, refining, and recycling operations using field-portable x-ray fluorescence (XRF) spectrometry and anodic stripping voltammetry (ASV). Preliminary results were given to the mining companies within 2 days of sample collection. The samples were then sent for confirmatory wet chemistry analysis using standard analytical methods. Future studies will use portable XRF spectrometry for multiple elements being developed at NIOSH's Health Effects Laboratory Division and a method for hexavalent chromium analysis by portable visible absorption spectrophotometry being developed by the Division of Applied Research and Technology.

Collaborators: This project is part of collaborative work with NIOSH's Division of Applied Research and Technology and the Health Effects Laboratory Division's Exposure Assessment Branch and Health Communication Research Branch.

CHARACTERIZATION AND COMMUNICATION OF CHEMICAL HAZARDS IN MINING AND PROCESSING

RESEARCHERS: Pamela Drake and Douglas Scott

AFFILIATION: Spokane Research Laboratory
National Institute for Occupational Safety and Health
(509) 354-8000

PURPOSE: Provide information on chemical hazards and assessment training to mine safety personnel to assist in protecting workers from chemical hazards.

RESEARCH SUMMARY: Exposure to airborne metallic particulates and other chemicals in the mining industry, particularly in milling and refining facilities, may expose thousands of workers to health risks. As reported in the 1996 National Occupational Health Survey of Mining Technical Report, NIOSH inventoried 2,570 different chemical substances and 84,939 trade name substances at 491 selected mine sites, and these substances were found to be the source of the largest potential exposure for workers. The Mine Safety and Health Administration (MSHA) recently enacted a Hazard Communication Standard (30 CFR 47), or the HazCom rule, that requires operators and contractors to assess the hazards of chemicals they produce or use and provide information to miners, MSHA, and NIOSH concerning the chemical hazards found at their mines. Under the HazCom rule, if operators produce a chemical or a chemical mixture they must "review available scientific evidence to determine if the material is hazardous." The rule becomes effective on June 30, 2002.

Many small- and medium-sized mining operations do not have the expertise to assess chemical hazards found at their mining, milling, and refining sites. This project will provide chemical hazard information and assessment training to mine safety personnel to assist in protecting workers from chemical hazards. We will provide technical assistance and develop printed materials, videos, and workshops concerning previous hazard assessments, industrial hygiene monitoring strategies, equipment and methods, and the health effects of particularly hazardous materials.

Workers in this type of industry tend to be kinetic learners; therefore, traditional training methods may be ineffective at actually changing the way a worker thinks about his/her own health and safety. Attendees at the Western Mining Summit held at SRL in January 2001 expressed the need for *practical* training techniques for adult learners in professional fields. To communicate risk effectively, there is a need for finding the most appropriate medium that will motivate workers who work in an innately dangerous environment to pay attention to the risks.

This is a new project for FY02.

Blasting agent fumes studies are done in NIOSH's explosion sphere. The fumes produced by 1-pound explosive charges are confined in the sphere pending sampling and analysis.

TOXIC FUMES FROM BLASTING

RESEARCHER: James H. Rowland III

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

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

KEYWORDS: Explosive, blasting agents, fumes, blasting

BIBLIOGRAPHY

NIOSH [2001]. Technology news 488: Migration of blasting fumes into a western Pennsylvania home. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

Rowland JH III, Mainiero RJ [2000]. Factors affecting ANFO fumes production. In: Proceedings of the 26th Annual Conference on Explosives and Blasting Technique. Vol. I. Cleveland, OH: International Society of Explosives Engineers, pp. 163-174.

Rowland JH III, Mainiero RJ, Hurd DA Jr. [2001]. Factors affecting fumes production of an emulsion and ANFO/emulsion blends. In: Proceedings of the 27th Annual Conference on Explosives and Blasting Technique. Vol. II. Cleveland, OH: International Society of Explosives Engineers, pp. 133-141.

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

To address the hazards of toxic fumes, a chamber has been constructed in which up to 10 pounds of blasting agent may be detonated and the toxic fumes confined. Following detonation of the blasting agent, the fumes are sampled to determine the quantities of CO, NO, NO_2, NH_3, and other toxic gases generated. Blasting agent formulations typical of those used in industry are evaluated to determine their relative fumes generation. Research has previously looked at the effects of confinement, water exposure, and contaminants on blasting agent fumes. In all cases, the tests were carried out in air. The next step is to observe the fumes production of blasting agents under conditions closer to those experienced in the field. This would involve evaluating the blasting agents in a low oxygen environment (similar to a borehole) and subjecting the blasting agent to the pressure pulses generated by earlier detonating boreholes. Field studies will be done to determine how the lab studies relate to the performance of blasting agents in commercial blasting.

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 blasting fumes 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.

Large-diameter propeller fan for underground stone mining.

INVESTIGATING AIR QUALITY ISSUES IN METAL/NONMETAL MINES

RESEARCHER: Roy H. Grau III

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

PURPOSE: Improve the air quality in metal/nonmetal mines to reduce the risk of adverse health effects from worker exposure to airborne contaminants such as diesel emissions, toxic fumes from blasting, and silica dust.

RESEARCH SUMMARY: Nearly all underground stone mines and many of the other metal/nonmetal mines have large openings that create ventilation with low air velocities. Underground metal/nonmetal miners are exposed to a variety of potentially harmful substances through the air they breath. Improving ventilation will reduce workers' exposure to these contaminants.

KEYWORDS: Underground mining, ventilation, diesel

Project personnel have determined some practical methods to improve ventilation in large, low-velocity mines. They are now researching a multitude of techniques to enhance the air quality of underground stone mines with large entries and low air velocities. Three important ventilation techniques have been identified and include mechanical fan selection and application, air coursing, and mine layout incorporating ventilation concepts.

Research is being done to determine the proper fan type selection and application to create the most efficient method for moving the air quantities that are required in these large-opening mines. The fan's positioning and auxiliary fan application are also very important. In addition, with the best fan selection, the air must be directed where it is needed the most. Project personnel are addressing the task of selecting the appropriate materials and methods for constructing air walls to direct the air. Included in this research is the application of rock stoppings.

Project personnel have found three different methods for mine layouts incorporating ventilation concepts to ventilate large-opening mines: (1) perimeter ventilation (ventilating the outside perimeter of the mine, which are the active faces), (2) unit ventilation (developing stone barriers between mining sections), and (3) split-mine ventilation (dividing the mine into one-half intake and one-half return with the separations (stone barriers) changing with mining). Most underground stone mines can incorporate at least one of these methods into their mine to improve air quality.

Tests of a GPS-based collision warning system for dump trucks and light vehicles (inlay: truck operation interface).

HAZARD DETECTION AND WARNING DEVICES

SAFETY ENHANCEMENTS FOR OFF-HIGHWAY DUMP TRUCKS

RESEARCHER: Todd Ruff

AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000

KEYWORDS: Collision warning, backup alarm, proximity alarm, mining equipment, dump truck

BIBLIOGRAPHY

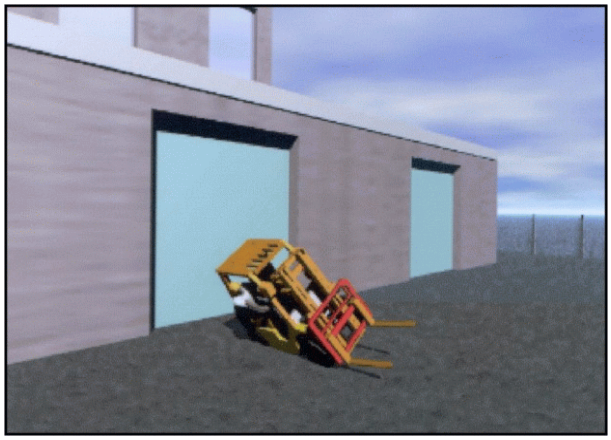
Ruff T [2001]. Test results of collision warning systems on off-highway dump trucks: phase 2. Spokane, WA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2001-100, RI 9654.

Ruff T [2001]. Application of radar to detect pedestrian workers near mining equipment. App Occup Env Hyg *16*(8):798-808.

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

RESEARCH SUMMARY: An average of 675 accidents and 21 fatalities involving powered haulage equipment occur each year in metal/nonmetal and coal surface mining operations. Twenty percent of these accidents involve off-highway dump trucks. Researchers will investigate methods of reducing common types of accidents involving dump trucks, specifically (1) accidents caused because of a truck driver's inability to see adequately around and in back of the equipment and (2) those caused when the truck driver loses control of the truck because of adverse conditions.

Technology will be investigated that can be applied to monitoring the blind areas around dump trucks to prevent collisions and backing over an edge. Research to date has shown that off-the-shelf collision warning systems developed for delivery vans and automobiles lack an adequate detection range and width to be effective on large dump trucks. New systems based on radar and radio signal detection have been developed recently using input from this project. An agreement with the Phelps Dodge Morenci mine in Arizona allows project personnel to test these new systems under actual operating conditions. Also, a prototype global positioning system (GPS)-based collision warning system has been developed under a contract with Trimble Navigation. This system uses standard GPS equipment, radios, and a Windows CE computer interface to allow an equipment operator to monitor the location of all equipment, small vehicles, and stationary structures nearby. Development and testing of this new system will continue this year.



Poor lift-truck operating practices, such as high-speed turns, can lead to serious accidents.

MOBILE MINING EQUIPMENT WARNING SYSTEMS

RESEARCHERS: John Owens, Wayne Howie, and Gregory Miller

**AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000**

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

KEYWORDS: Mining, warning system, rollover, control technology, lift trucks

RESEARCH SUMMARY: Unstable configurations and poor operating practices during the operation of lift trucks, front-end loaders, skid-steer loaders, highway trucks, and dozers result in numerous accidents. A common danger in the mining industry occurs when mobile mining equipment is unknowingly operated in an unstable configuration or in dangerous conditions. Such instabilities can be initiated through both operator error and changing terrain and can result in equipment rollovers and the deaths of workers.

Despite improvements in the equipment, lift trucks are involved in 68,000 (serious and nonserious) injuries annually in the United States. More than 600 accidents involving lift trucks have been recorded at mining operations during the last 5 years. A monitoring system is being developed that will monitor the critical operating parameters of lift trucks. By monitoring a lift truck's operation, it may be possible to determine why accidents continue to occur. The role of driver error as contributing to accidents will be evaluated. If driver error is determined to be a significant contributor to lift truck accidents, then a warning system will be developed. The research is being performed in five phases. The first phase involves developing a lift truck testbed. The second phase will develop an electronic monitoring system to monitor the testbed. The third phase will involve data collection from a lift truck in operation. The fourth phase will be to evaluate the data to identify critical operating parameters that signify unsafe lift truck operating practices. The fifth phase will involve designing a system to monitor these critical operating parameters and trigger an alarm whenever a critical combination of these factors occurs.

BIBLIOGRAPHY

Maleki H, Owens J [2001]. Application of computational and statistical techniques to an evaluation of mobile roof supports. In: Desai SS, Kundu T, Hatpalani S, Contractor D, Kemeny J, eds. Proceedings of the 10th International Conference on Computer Methods and Advances in Geomechanics. Vol. 2, pp. 1705-1711.

Howie W, Owens J [1999]. Mobile roof support load rate monitoring system. In: Proceedings of the IEEE Industry Applications Society (Phoenix, AZ, Oct. 3-7). Vol. 1, pp. 234-239.

Maleki H, Owens J, Endicott M [2001]. Evaluation of mobile roof support technologies. In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 67-77.

WSDOT dump truck used to evaluate collision warning systems.

EVALUATING COLLISION WARNING SYSTEMS FOR CONSTRUCTION EQUIPMENT

RESEARCHER: Todd Ruff

AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000

PURPOSE: Evaluate existing collision warning systems on equipment used on roadway construction projects and make recommendations to industry on their use. A selection of one or more systems will be made for long-term tests to be conducted under the project "Evaluating Roadway Construction Work Zone Interventions" at the NIOSH Division of Safety Research (DSR).

KEYWORDS: Collision warning, backup alarm, proximity alarm, construction

RESEARCH SUMMARY: Highway and street construction workers are at risk of fatal and serious injury when working near passing motorists and construction equipment. During 1992-98, 841 highway and street construction workers were fatally injured. In 55% of these cases, the death was either vehicle- or equipment-related and occurred in the work zone. In 68% of the vehicle- and equipment-related fatalities within work zones, a worker on foot was struck by a vehicle. Victims were as likely to be struck by a construction vehicle as by a passing traffic vehicle.

This project is a collaborative effort with two other projects, one at DSR and one at the Pittsburgh Research Laboratory (PRL). The sponsoring project, "Evaluating Roadway Construction Work Zone Interventions," calls for three tasks. The first task at DSR involves evaluation and design of traffic control interventions and methods to reduce worker exposure to moving equipment. The second task at PRL involves the development of a new device called HASARD that will prevent collisions between pedestrian workers and equipment. The third task at SRL will evaluate existing technologies that can be used to prevent collisions between pedestrian workers and equipment used at roadway construction sites. An agreement with the Washington State Department of Transportation (WSDOT) has been established that allows NIOSH to test collision warning systems on WSDOT equipment. The equipment will be selected by WSDOT and NIOSH based on exposure risk and past accident rates. Tests consist of 3-month evaluations of each technology to evaluate their effectiveness in preventing collisions. To date, radar, cameras, and ultrasonic systems have been tested on dump trucks and sanding trucks. These evaluations will allow one or more systems to be selected for longer term tests at a highway construction site.

Haul trucks at a limestone quarry.

EVALUATING ROADWAY CONSTRUCTION WORK ZONE INTERVENTIONS

RESEARCHER: Gary L. Mowrey, Ph.D.

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6648

KEYWORDS: Traumatic injuries, work zone, mining, proximity warning, collision avoidance, HASARD, heavy equipment

BIBLIOGRAPHY

Pratt SG, Fosbroke DF, Marsh SM [2001]. Building safer highway work zones: measures to prevent workers injuries from vehicles and equipment. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2001-128.

Schiffbauer WH [1999]. A workplace safety device for operators of remote-controlled continuous mining machines. Amer J Ind Med *36*(Suppl 1): 69-71.

PURPOSE: Develop, evaluate, and demonstrate interventions aimed at reducing worker exposure to moving vehicles and equipment at surface mine sites and inside the boundaries of work zones.

RESEARCH SUMMARY: Statistics from the Mine Safety and Health Administration (MSHA) for 1995-98 show that an average of 13 miners are killed each year by being run over or pinned by mobile mining equipment. At surface mines, these accidents often involve large dump trucks that drive over a smaller vehicle or a worker that is in a blind spot of the truck. Over one-half of these accidents could have been avoided if the equipment operator had been adequately warned of the impending collision. MSHA is considering regulations that would require the use of some type of blind-spot sensor, such as a proximity- or collision-warning system (30 CFR 56, 57, 77).

Highway and street construction workers are also at risk of fatal and serious nonfatal injury when working near construction vehicles and equipment. During 1992-98, 841 highway and street construction workers were fatally injured. In 465 (55%) of these cases, the death was vehicle- or equipment-related and either clearly or probably occurred in the work zone. In 318 of the 465 vehicle- and equipment-related fatalities within work zones, a worker on foot was struck by a vehicle.

Protocols are being written and a work zone analysis system (WZAS) is being developed for accurately measuring and objectively monitoring workers interacting with mobile equipment at work sites. In FY02, the WZAS is to be tested and evaluated for doing time and motion studies.

This project supports the National Occupational Research Agenda traumatic injuries research area. It is a collaboration between researchers at the Pittsburgh Research Laboratory (PRL), the Division of Safety Research (DSR), and the Spokane Research Laboratory (SRL) who have multidisciplinary expertise in mining and roadway work zone interventions. Specific aims include modification of the Hazardous Area Signaling and Ranging Device (HASARD), which is a NIOSH-developed proximity sensing and alarming device for use on heavy mobile equipment (PRL); design and development of a WZAS (PRL); assessment of internal traffic control plans (DSR); and evaluation of off-the-shelf proximity sensors (SRL). The combined efforts of the three labs/divisions are expected to hasten the development of new intervention techniques (innovative safety warning devices) to help protect workers on foot in areas where mobile equipment is present.

Workers around a highwall mining conveyor system.

LOCKOUT/TAGOUT, JAMMED AND MOVING MACHINERY CONTROLS

RESEARCHER: Gary L. Mowrey, Ph.D.

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6648

PURPOSE: Develop an electromagnetic-based proximity-warning system to provide warning and/or shutdown for workers operating or performing maintenance on moving machinery.

KEYWORDS: Lockout, tagout, jammed, machinery, proximity warning, object detection, conveyor, baler, maintenance, HASARD, traumatic injury

RESEARCH SUMMARY: Lockout/tagout (LOTO), Occupational Safety and Health Administration (OSHA) Standard 29 CFR 1910.147, is a protective procedure that workers must do to remove hazardous energy from machinery before performing maintenance tasks. All energy sources for equipment must be deenergized, and the disconnecting means must be locked and labeled with a tag warning not to energize the machinery. Each year about 150 workers die and nearly 7,000 are seriously injured from being caught in machinery. About one-half of these workers were performing service- or maintenance-related tasks at the time of the incident. LOTO violations rank fourth on OSHA's list of the top 10 most frequently cited standards. Moreover, both the Mine Safety and Health Administration and the National Stone Association have found that concern about LOTO is one of the most important safety issues facing the mining and aggregate industries.

A patented active proximity-warning device called the Hazardous Area Signaling and Ranging Device (HASARD), originally developed for use on underground continuous mining machines, is currently being redesigned for various types of industrial machinery, with initial emphasis on conveyor-type equipment. HASARD warns workers who approach a previously defined hazard zone (or zones) around a machine in normal operation and/or during maintenance-related tasks. This system has the potential to be modified to disable the power in the event of the employee's failure to lockout and tagout the machine. Protocols have been completed, and equipment has been acquired for testing and evaluating HASARD and for making accurate distance measurements between a worker and a piece of equipment, such as a conveyor belt. A computer-controlled X-Y-Z positioning table (for recording HASARD receiver outputs in three dimensions) and a two-dimensional scanning laser measurement system (for accurately determining distances between a worker and moving machinery) will be used in lab testing and evaluation.

This project supports the National Occupational Research Agenda traumatic injuries research area. It is a collaboration between researchers at the Pittsburgh Research Laboratory and the Division of Safety Research (DSR) who have expertise in machine safeguarding innovation. DSR is concurrently developing a low-cost, strain-gauge-based interlock for detecting the formation of jams in dangerous machinery. The combined efforts of the two entities are expected to help reduce the frequency of fatalities and injuries associated with workers being caught in various types of moving machinery.

BIBLIOGRAPHY

Schiffbauer WH [1999]. A workplace safety device for operators of remote-controlled continuous mining machines. Amer J Ind Med *36*(Suppl 1): 69-71.

ADVANCE WARNING OF GROUND STABILITY HAZARDS

RESEARCHERS: Steve Signer, Lewis Martin, and Jeff Johnson

AFFILIATION: Spokane Research Laboratory
National Institute for Occupational Safety and Health
(509) 354-8000

KEYWORDS: Remote monitoring, strain, ground stability

BIBLIOGRAPHY

Signer S, Rains R [2001]. A case study of bolt loads in a trona mine retreat section. In: Roofbolting in Mining, Aachen International Mining Symposia (Aachen, Germany, June 6-7). Aachen, Germany: Institut für Bergbaukunde I, pp. 481-494.

Signer SP and Rains R [2001]. Effects of bolt spacing, bolt length, and roof span on bolt loading in a trona mine. In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 302-308.

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: Mine Safety and Health Administration statistics indicate that there is a dire need to warn underground miners of unexpected ground stability hazards. Although research studies conducted by the former U.S. Bureau of Mines and NIOSH have demonstrated that geotechnical instruments can be used effectively to identify and monitor ground control hazards, modern rock mechanics instruments are rarely used by the mining industry. Most mines, especially 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 due to unexpected roof and rib falls.

To obtain ground stability information from locations that have traditionally been difficult to monitor, such as mined-out areas, active mining stopes, retreat mining faces, and tailgate entries, cableless techniques will be developed to monitor instruments remotely. A prototype miniaturized data acquisition system has been developed that can measure and record strain readings on 16 strain gauges for more than a year without long lead wires. This system will be used in conjunction with a new strain sensor and previously developed instrumented roof bolts.

Lab tests of the miniature data acquisition system and strain sensor are 80% complete. Next year the instruments will be tested in the field. Hazardous levels of horizontal, vertical, and shear strain that can lead to rock failure will be detected using this technology so that a warning signal can be given and corrective action taken.

Anomalous deformation of the roof might indicate an impending roof rall.

WIDE AREA ROOF FALL DETECTION AND WARNING SYSTEM

RESEARCHERS: **Eric Zahl, John Dunford, and Mark Larson**

AFFILIATION: **Spokane Research Laboratory**
National Institute for Occupational Safety and Health
(509) 354-8000

PURPOSE: Document and assess technologies to detect rock block movements in the most active underground workplaces so that miners can be warned of conditions that might lead to a roof fall. Assess deformation mechanisms so rock movement can be interpreted correctly.

RESEARCH SUMMARY: Statistics from the Mine Safety and Health Administration show that 80% of roof fall fatalities occurred within 100 feet of the working face and 56% happened within 25 feet of the face. In addition, 42% of the falls occurred within 1 hour of a roof examination. Most of the falls (61%) occurred in supported ground that was supposedly safe. Relatively small falls are not readily predictable by off-the-shelf geotechnical sensors. Rapid face advance rates and rapidly changing ground conditions only complicate the detection problem.

Specific tasks within the project include surveillance, a review of sensing technology, a review of data acquisition and processing technology, and assessment of the characteristics of various time-dependent failure mechanisms. Sensing technologies to be evaluated will include stress-, strain-, and displacement-monitoring sensors, seismic and tomographic techniques, and acoustic and electromagnetic devices, as well as photogrammetric and image analysis methods. The project will determine the feasibility of a monitoring system that would operate in near-real time, cover a wide area within 100 feet of the working face, and assess the condition of the immediate roof. Low cost and ease of installation in the work place are critical evaluation criteria. The goal is to provide information about the condition of the entire roof in the immediate working area.

KEYWORDS: Underground mining, ground control, monitoring systems, sensor technology

A 22-ton rough-terrain construction crane energized at 4,000 V ac for current measurement tests on a concrete test surface.

OVERHEAD POWER LINE CONTACT ALARM FOR MOBILE EQUIPMENT

RESEARCHER: James C. Cawley

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6648

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

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

RESEARCH SUMMARY: Overhead electric power lines are a serious electrocution hazard to crane, truck, and drill rig operators. They cause about one-fifth of all fatal electrocutions in the mining industry. Detailed analysis of past accidents has shown that in over 50% of the cases, workers were not aware of the overhead line contact until one or more workers subsequently dismounted or touched the energized equipment and were injured. The widespread use of a reliable overhead power line contact alarm on mobile equipment could reduce the number of injuries and fatalities from equipment-line contacts. A practical contact alarm could be applied in construction, agriculture, and public utilities where overhead power lines are also a hazard.

Early research showed that electrical currents flowing through a vehicle in contact with a high-voltage power line were of sufficient magnitude to be practically detected and trigger an alarm. An alarm device would warn equipment operators and nearby coworkers that the vehicle is an electrocution hazard and should not be approached (or dismounted by the operator).

Recent work measured the current flow through a 22-ton rough-terrain construction crane and a 23-ton dump-bed truck on 30- by 50-ft test surfaces of concrete, asphalt, gravel, bare earth, and grass. Experiments confirmed that for rubber-tired vehicles sufficient, current flow exists on all surfaces except clean, dry asphalt, which is highly resistant to the flow of electrical current. In addition, when the crane's outriggers are blocked up on oak planks, current flow is insufficient to trigger an alarm device. While this does not reduce the electrocution hazard for workers, it negates the use of current detection as a universal mechanism to actuate an alarm device. The experimental focus has shifted to investigate other detection mechanisms in the final year of the project.

BIBLIOGRAPHY

Hinze J [1996]. Analysis of fatalities and injuries due to power line contacts. J Constr Eng Mgt *22*(2):177-182.

NIOSH [1995]. NIOSH alert: preventing electrocutions of crane operators and crew members working near overhead power lines. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 95-108.

Data acquisition at the Galena Mine, Wallace, ID.

INVESTIGATION OF ELECTROMAGNETIC PRECURSORS TO ROCK BURSTING

RESEARCHERS: Doug Scott and Theodore Williams

AFFILIATION: Spokane Research Laboratory
National Institute for Occupational Safety and Health
(509) 354-8000

KEYWORDS: Underground mining, electromagnetic emissions, monitoring instruments

PURPOSE: Develop a method to measure and monitor electromagnetic emissions during the mining cycle in order to develop a method that will alert miners to the possibility of imminent ground failure.

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 death. 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 of warning miners of imminent ground failure.

Two data acquisition systems that monitor both acoustic and electromagnetic emissions in the rock have been in operation intermittently at the Galena Mine, Wallace, ID, for several months. The systems are configured to run from either ac or dc power, and one of the systems is capable of collecting up to 1 million samples per second. Currently, both systems are located in a "quiet" (aseismic) area of the mine. However, two 350-ft antennas and a geophone have been installed on the 5500 level (which is seismically active) to monitor both electromagnetic and acoustic emissions in a nearby stope. If an association exists between the frequency of electromagnetic emissions and seismic activity, additional stopes will be monitored.

Mine fire sensor array in the Safety Research Coal Mine.

SMART FIRE SENSORS

RESEARCHER: John C. Edwards, Ph.D.

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

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

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

The two methods that are being used to develop smart fire sensor technology are (1) grouping fire sensors that are POC-specific and using a neural network to provide this decision capability and (2) developing or improving fire detector technology that will provide early-warning detection while functioning reliably in atmospheres containing diesel exhaust or welding and cutting emissions. In-mine fire experiments are being conducted to evaluate the sensors and deployment strategy. The large-scale experiments are being conducted in the Safety Research Coal Mine. This in-mine research examines sensor response to signatures from smoldering and flaming coal, electrical cable, conveyor belt fires, and flaming diesel fuel fires with and without nuisance background diesel emissions. The most efficient arrays of multiple fire sensors, which include chemical cell and metal oxide semiconductor gas sensors and ionization and optical smoke sensors, are being evaluated for mine fire combustible source identification, discrimination of mine fire POC from diesel emissions as a supplement to chemical cell CO sensors that are cross-sensitive to H_2 at a battery-charging operation, and for early detection of very low CO-emitting smoldering combustibles that produce visually obscuring smoke. An in-mine experiment is being conducted at a battery-charging station in a western Pennsylvania mine to validate the use of multiple discriminatory mine fire sensors to eliminate false alarms due to H_2 cross-interference on a CO sensor.

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, its rate of change at a smart fire sensor location, and smoke reversal from a fire in a ventilated airway. This research is to be done in cooperation with the Mine Safety and Health Administration, sensor manufacturers, and mine operators.

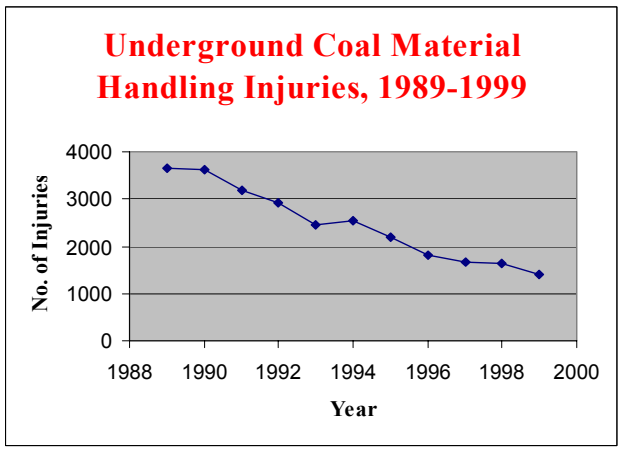
KEYWORDS: Fires, mining, detection

BIBLIOGRAPHY

Edwards JC, Franks RA, Friel GF, Lazzara CP, Opferman JJ [2001]. Discriminatory mine fire source detection. In: Proceedings of the Seventh International Mine Ventilation Congress (Krakow, Poland): pp. 291-298.

Edwards JC, Franks RA, Friel GF, Lazzara CP, Opferman JJ [2001]. Underground fire detection and nuisance alarm discrimination. Coal Age *106*(7):70-72.

Hwang CC, Edwards JC [2001]. CFD modeling of smoke reversal. In: Proceedings of the International Conference on Engineered Fire Protection Design. Bethesda, MD: Society of Fire Protection Engineers, Inc., pp. 376-387.



INJURY PREVENTION AND EQUIPMENT DESIGN

MATERIALS HANDLING ACCIDENT REDUCTION IN UNDERGROUND MINES

RESEARCHERS: Bill Stewart, Michael Beus, Curtis Clark, and Phil Patton

AFFILIATION: Spokane Research Laboratory
National Institute for Occupational Safety and Health
(509) 354-8000

KEYWORDS: Underground mining, materials handling, overexertion, mine hoisting

BIBLIOGRAPHY

Patton PW, Stewart B, Clark CC [2001]. Reducing materials handling injuries in underground mines. Presentation at the 32nd Institute on Mining Health, Safety and Research, Salt Lake City, UT, Aug. 5-7.

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

RESEARCH SUMMARY: Number of injuries, activity at the time of injury, and the source of the injury are specific types of information needed to identify the causes of injuries from the manual handling of materials in underground mines. Emphasis will be placed on how to mechanize these tasks, change the way manual tasks are done, or eliminate the tasks. Injuries caused by lifting objects that are too heavy, twisting while lifting, lifting in awkward positions, and handling the same supplies numerous times result in numerous injuries each year. Examples include lifting supplies while loading and unloading; moving power cables; lifting machine parts during maintenance and repair; handling coal, rock, or waste; and lifting timbers. Types of interventions include the use of assisted lifting devices, adding lifting attachments to existing equipment, studying ways to increase working space in areas where a lot of material is handled, and investigating methods to reduce materials rehandling. Work has also begun on a materials-handling best-practices document. This document will include innovative materials-handling methods currently in use, new materials-handling ideas and practices, and detailed analyses (using fault-tree analysis) of materials-handling system failures and back injuries.

A conveyance monitoring system has been developed to provide hoist operators and inspection and enforcement personnel with a real-time indicator of the operational status of a mine shaft conveyance. The system ensures that mine conveyances are operating within the load and speed regulations required by law (30 CFR 57.19021). Data on conveyance payload, wire rope end loads and safety factors, position, speed, acceleration, guide displacement, battery voltage, and temperature are displayed in real time. Current work is focused on measuring end loads while moving heavy equipment, ore, and supplies in and out of underground mines. Results are being analyzed using particle flow code (PFC). Dynamic rope loads resulting from impact of ore on an empty skip during the loading phase and acceleration changes during hoisting are significant components that need to be incorporated into calculations of rope safety factors. Shaft hoist rope will be modeled the model will be subjected to static and dynamic end loads, and the calculated tension compared to field measurements of load. This work should ensure that mine hoisting activities operate within the limits set by safety regulations.

Operating construction equipment at a training site in California.

REDUCING INJURY RISK FROM JOLTING AND JARRING ON MOBILE EQUIPMENT

RESEARCHERS: **Fred Biggs and Kumar Kittusamy**

AFFILIATION: **Spokane Research Laboratory**
National Institute for Occupational Safety and Health
(509) 354-8000

KEYWORDS: Vibration, shocks, heavy equipment, jolting, jarring

PURPOSE: Identify sources of jolting and jarring on mining, agricultural, and construction equipment. Demonstrate the most promising interventions and transfer research results and technologies to industry for implementation and subsequent reduction of jolting- and jarring-related injuries.

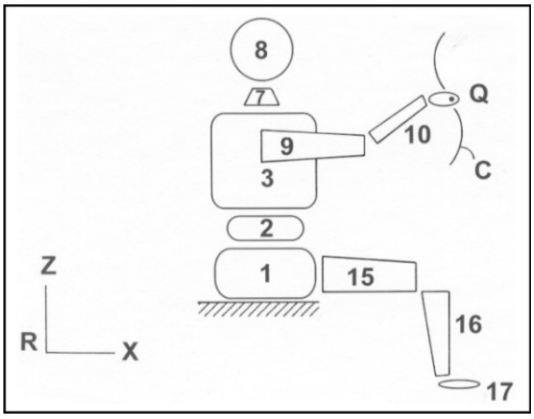
RESEARCH SUMMARY: Data from the *Construction Chart Book* and the U. S. Bureau of Labor Statistics show that, in 1994, 24.5% of the nonfatal injuries in the construction industry were back injuries. In 1993, estimates of lost-time injuries by body part indicate that, nationally, 15% of the injuries to farm workers were back injuries. Back injuries are also the most costly nonfatal injury. Data from the Washington State Department of Labor and Industries for 1992-97 showed an average annual cost for back injuries as $175,720,000, about twice as high as for any other category. During 1986-95, truck drivers at surface mines accounted for about 63% (76 of 120) of the fatalities and 60% (3,551 of 5,569) of the lost-time injuries at surface mines.

While a great deal of research has been done on whole body vibration and its effect on the human body, particularly the musculoskeletal system, very little has been done on the effects of single or multiple jolts and jars. It is important to understand the mechanism whereby an injury may be caused by a single jolt, as well as what magnitude of jolt may result in an injury.

The investigative approach will include these major steps or tasks.

- Selecting field sites at which to collect data on jolting and jarring.
- Analyzing the ergonomics of the various field site operations.
- Identifying interventions needed for reducing injury risk to workers.
- Testing or demonstrating selected interventions.
- Documenting and transferring research results to all relevant stakeholders.
- Publicizing findings through technical conferences and meetings, peer-reviewed journals, and NIOSH publications.

Collaborators: The project involves the collaboration of NIOSH's Pittsburgh Research Laboratory and the Division of Applied Research and Technology.



A biomechanical model of a heavy equipment operator.

BIOMECHANICAL MODELING OF JARRING AND JOLTING

RESEARCHER: **Thomas R. Waters, Ph.D.**

AFFILIATION: **Division of Applied Research and Technology**
National Institute for Occupational Safety and Health
(513) 533-8147

KEYWORDS: Shocks, jolting, jarring, low back pain, biomechanical modeling, heavy-duty equipment operators

PURPOSE: Develop, evaluate, and implement a biomechanical model of the human operator for estimating the potential health impacts of jolting and jarring injuries among haulage truck and other heavy equipment operators in mining, agriculture, and construction.

RESEARCH SUMMARY: Little research has been done related specifically to shock trauma injuries (jolting and jarring injuries caused by haulage trucks) or to developing engineering controls to reduce such injuries. This study is aimed at developing a computer model of the human operator that will provide an estimate of loading to the spinal column due to exposure to jarring and jolting from operating heavy mobile equipment.

Tasks include (1) developing a link-segment biomechanical model to allow evaluation of the loading associated with exposure to jarring and jolting accelerations; (2) evaluating jarring and jolting acceleration exposure data from field studies of heavy equipment operators in mining, construction, and agriculture; and (3) evaluating the effectiveness of interventions to reduce jarring and jolting exposures for heavy equipment operators.

This project is a collaborative effort among the Spokane and Pittsburgh Research Laboratories and the Division of Applied Research and Technology.

BIBLIOGRAPHY

Li F, Huston RL, Waters TR [2001]. Musculoskeletal dynamics of heavy equipment operators. In: Das B, Karwowski W, Mondelo P, Mattila M, eds. Proceedings of the International Conference on Computer-Aided Ergonomics and Safety (Maui, HI, July 29-August 1, 2001).

Logo developed to enhance awareness of the ergonomics process established by the team at a cooperating mine site.

ERGONOMICS INTERVENTIONS IN MINING

RESEARCHER: Richard L. Unger

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6648

KEYWORDS: Mining, ergonomics, musculoskeletal disorders

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

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

The first phase of this research consisted of MSD risk factor assessments at underground coal, surface copper, surface phosphate, and underground limestone operations. The results were used to identify activities that provide significant risk for injury and to develop general risk-reduction strategies. The primary benefit to the cooperating mine sites was a better understanding of the types of ergonomic risk factors at their operations and how to identify them. Once identified, the mines can prioritize the risk factors and develop strategies for reducing them.

The second, ongoing phase involves development, implementation, and evaluation of ergonomics interventions at a cooperating surface coal mine. To this end, NIOSH researchers have established an ergonomics process at the mine site, where they have collected comprehensive baseline data, familiarized themselves with the mines' characteristics, helped the mine upgrade its injury data collection and analysis process, assisted in establishing a permanent ergonomics committee, and administered ergonomics awareness training to the entire workforce.

Remaining work includes collecting occupation- and task-specific data using customized data collection tools; determining intervention approaches for hazard reduction; developing specific plans for implementing interventions, including engineering and administrative controls; introducing the interventions; and evaluating their effectiveness.

BIBLIOGRAPHY

Cornelius KM, Turin FC, Wiehagen WJ, Gallagher S [2001]. An approach to identify jobs for ergonomic analysis. In: Proceedings of the IIE Annual Conference (Dallas, TX). Norcross, GA: Institute of Industrial Engineers.

Winn F, Biersner R, Morrissey S [1996]. Exposure probabilities to ergonomic hazards among miners. Int J Ind Ergonomics *18*:417-422.

Zhuang Z, Groce D [1995]. The national occupational health 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, U.K.: Taylor and Francis, pp. 273-280.

The distance between the first step and the ground can be the most difficult part of equipment access.

REDUCING SLIPPING AND FALLING INJURIES AT SURFACE MINES

RESEARCHER: Floyd Varley

AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000

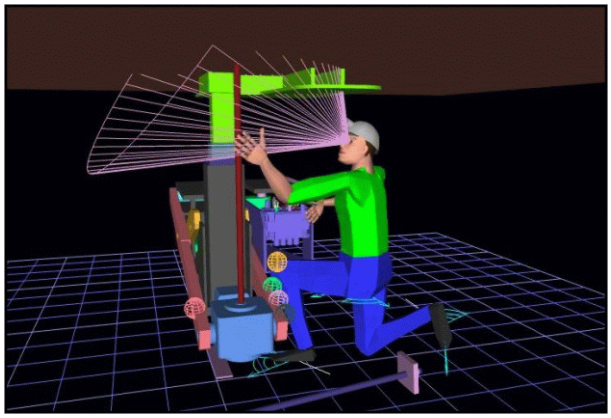
KEYWORDS: Slipping, equipment access, falling, surface mine safety, accident prevention

PURPOSE: Reduce injuries resulting from slips and falls at surface mines. Conditions leading to slips and falls will be identified to (1) identify the sources of slips and falls, (2) design intervention techniques to prevent slip and fall injuries, and (3) demonstrate the most promising interventions, focusing on mine equipment design and human factors.

RESEARCH SUMMARY: A significant fraction (27%) of accidents in mining are associated with tripping and slipping accidents. The severity of these accidents is often greater with older workers because of diminished flexibility with age. This is a particular problem in the mining industry where the average age of employees is 47 years. Surface metal and nonmetal mine accident data show that over 10% of all accidents in mining operations occurred while an operator was mounting or dismounting from a vehicle using the ladder portion of the steps. An investigation of where these accidents occurred found an increasing rate of equipment access injuries among (1) the largest metal operations and (2) the smallest stone, sand, and gravel operations.

The investigative approach to reduce slipping and falling injuries will focus on mine equipment design and human factors. Equipment design research will include improved methods of mounting and dismounting equipment. In-mine trials of retractable access systems are planned to begin in FY02. Human factor research will include analyses of older miners' risks for slipping and falling injuries using MSHA accident database and surveillance data and field investigations to identify risks for slipping and falling injuries among mine personnel. Technology will be transferred through the development of effective behavioral, organizational, and/or educational interventions to address the leading causes of slip and fall injuries.

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



Computer simulation is being used in research to determine safe boom speeds for roof bolters.

HUMAN FACTORS DESIGN FOR MACHINE SAFETY

RESEARCHER: Dean H. Ambrose

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6648

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

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

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

The approach is to identify machine hazards through surveillance data and stakeholder input and to develop engineered interventions through the application of human factors design principles, computer-based design and analysis tools, and lab and field experimentation. Specific machine problems being investigated are safe roof bolter appendage speed and the jarring/jolting of mobile equipment operators. The bolter research involves the use of computer models, in addition to lab and field experimentation, to study the problem and develop recommendations for safe boom speeds. In FY02, research data collection and analysis are to take place after validating the bolter model. Specific improvements to seating and alternative suspension systems are being evaluated for isolating the operator from excessive body vibrations. The mine operator jarring/jolting research completed field trials on redesigned shuttle car seats for low- and mid-seam underground coal mines.

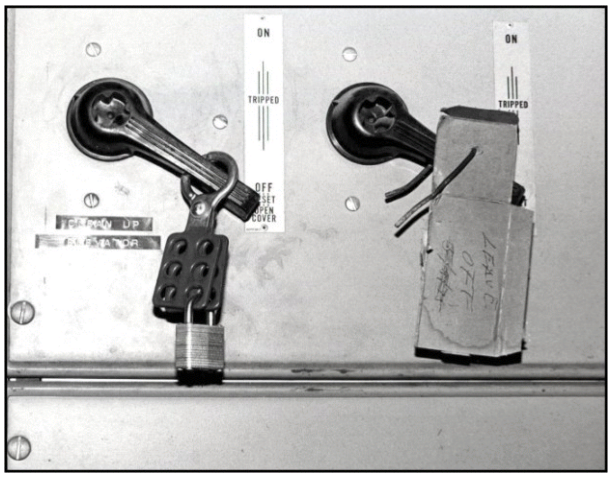
In FY2000, jolting/jarring research was extended to agriculture. With the cooperation of The Pennsylvania State University's Farms, researchers collected whole-body vibration data on six different farm tractors during seasonal baling, mowing, hauling, and spreading operations. Also collected were ergonomic data on the tractor's operator compartment and seat using a checklist for evaluating cab design on tractors and other mobile farm equipment. This project is producing design guidelines and improved hardware related to equipment hazards to improve machine safety in the mining and agriculture industries.

BIBLIOGRAPHY

Ambrose DH [2001]. Random motion capture model for studying events between a machine and its operator. In: Proceedings of the Advanced Simulation Technologies Conference. San Diego, CA: Society for Computer Simulation International, pp. 127-134.

Bartels JR, Ambrose DH, Wang RC [2001]. Verification and validation of roof bolter simulation models for studying events between a machine and its operator. Warrendale, PA: Society of Automotive Engineers, Inc., technical paper 2001-01-2088.

Mayton AG, Merkel R, Gallagher S [1999]. Improved seat reduces jarring/jolting for operators of low-coal shuttle cars. Min Eng *51*(12):52-56.



Improperly locked and tagged disconnects jeopardize the safety of maintenance personnel.

FUNDAMENTAL STUDIES IN ELECTRICAL HAZARDS

RESEARCHER: Michael R. Yenchek

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6648

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

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

BIBLIOGRAPHY

Novak T, Fisher TJ [2000]. Lightning propagation through the earth and its potential for methane ignitions in abandoned areas of underground coal mines. In: Conference Record of the 2000 IEEE Industry Applications Conference, 35th IAS Annual Meeting and World Conference on Industrial Applications of Electrical Energy (Rome, Italy), pp. 2674-2681.

Yenchek MR, Cawley JC, Brautigam AL, Peterson JS [2000]. Distinguishing motor starts from short circuits through phase-angle measurements. In: Conference Record of the 2000 IEEE Industry Applications Conference, 35th IAS Annual Meeting and World Conference on Industrial Applications of Electrical Energy (Rome, Italy), pp. 2695-2702.

RESEARCH SUMMARY: Electrocutions account for more than 5% of all occupational fatalities, 14% of all deaths in the construction industry, and 5% of all deaths in the mining industry. 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 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, a topic of concern because of lightning-initiated gas explosions in gob areas of the mine.

Continuing analysis of electrical incident narratives from the U.S. Bureau of Labor Statistics shows that fatal occupational electrical incidents can be separated into five roughly equal categories. One-fifth of fatal occupational electrical incidents occur during the installation or maintenance of low-voltage light fixtures, circuit breakers, transformers, cables, HVAC equipment, and residential/industrial appliances and equipment. About 20% occur while performing tasks unrelated to electrical work activities, such as using power tools with defective cords/grounds, portable generators, welders, or power washers or doing plumbing work. One-fifth occur when a long metallic object, such as a ladder or a pipe, is hand-carried into an overhead power line. One-fifth occur when high-reaching mobile equipment, such as cranes or boom trucks, accidentally contacts a power line. The remaining incidents occur during the construction or maintenance of power lines or result when workers are struck by lightning.

The wide variety of work activities, equipment, environmental conditions, occupations, and skill ranges of those fatally injured by electricity on the job suggests that no single intervention strategy can eliminate occupational electrical fatalities. Accordingly, in this latter stage of the project, researchers are holding discussions with entities such as the Center for the Protection of Workers Rights and the Construction Safety Council to devise a coordinated effort to increase electrical safety by focusing on engineering controls, organization of work, training, and personal protective equipment.

Lightweight jackleg drill—30 pounds lighter than a standard drill steel.

INJURY PREVENTION FOR METAL/ NONMETAL DRILLING AND BOLTING OPERATIONS

RESEARCHER: Robert McKibbin

AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000

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

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. Current research is focused on reducing the weight of jackleg drills.

RESEARCH SUMMARY: Statistics from the Mine Safety and Health Administration have shown that in an average year there are 2 fatalities and more than 200 injuries in drilling and bolting operations in metal/nonmetal mines. This accounts for 5% and 4% of all fatalities and injuries in these mines, respectively.

Project staff have highlighted a number of areas in which reductions in accidents might be realized. A significant finding was the number of injuries related to the weight (about 103 pounds) of jackleg drills. Such injuries result in about 35 lost-time injuries per year, or about 17% of all drilling and bolting injuries in metal/nonmetal mines. Almost all of these are low-back injuries.

One course of research offering a good probability of short-term success was the fabrication and testing of an improved jackleg drill. The initial goal was to reduce the weight to 83 pounds without a reduction in the specific energy of drilling. A drill was constructed in which several components were made of aluminum or titanium, resulting in a machine that is 20% lighter than a standard steel drill. Initial tests of this prototype in both the lab (in concrete blocks) and in a mine (hard quartzite) has shown it is capable of drilling with no loss of penetration rate or increase in noise. A second-generation drill is now being fabricated in which some of the titanium components will be replaced with nikasil-coated aluminum. The aluminum is lower in cost and easier to machine and weld than titanium. The resultant savings should enhance industry willingness to try the new drill.

In addition to the weight reduction already achieved, several alternative jackleg handles were designed and are in the process of being fabricated. These designs address concerns about vibration and fatigue experienced by miners and include both vibration-dampening and improved ergonomic shapes.

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

Testing dynamic loads at SRL's scaled ore pass test facility.

SAFETY ISSUES OF STORAGE AND TRANSPORT OF BULK SOLIDS

RESEARCHERS: **Stephen Iverson and Michael Beus**

AFFILIATION: **Spokane Research Laboratory**
National Institute for Occupational Safety and Health
(509) 354-8000

PURPOSE: Reduce the frequency of injuries and fatalities related to the storage and transport of bulk materials in mining.

RESEARCH SUMMARY: Accidents and safety issues related to storage and transport of bulk solids are numerous. U.S. Bureau of Labor Statistics data on fatal occupational injuries for 1992-98 indicated that 229 work-related fatalities relating to bulk storage occurred in the United States. In structures such as bins and silos, the impact of falling particles may cause damage and failure to walls and gate assemblies. Material bridging and structural failures in bins, silos, hoppers, and pipeline trenches cause accidents in the construction and agricultural industries.

Handling and storing of bulk materials is common throughout the mining industry. The FY99 Strategic Planning Report for the Office for Mine Safety and Health Research has identified "bulk materials" as a problem area not sufficiently addressed by NIOSH in ongoing mining research programs. It was identified as a research gap in all segments of mining, from underground and surface mining operations to prep plants.

Computer modeling using distinct elements is an emerging method for improving the understanding of bulk solids flow problems. Modeling of flow problems in mine ore passes or for surface storage piles will provide insights into problems with current designs. Significant effects have been seen in ore passes because of particle size distribution, particle geometry, physical properties of ore and waste material (particularly cohesion), and geometry of the ore pass itself. Computer modeling is largely restricted to geotechnical research professionals who have considerable resources available for developing realistic input variables and interpreting and applying the results. These highly sophisticated computer modeling routines need to be adapted as a practical design tool by engineers at mining operations.

Generally, this project proposes (1) identification of the root causes of accidents during storage and transport of bulk materials, (2) identification and design of intervention techniques to prevent bulk materials storage and transport injuries and fatalities, (3) demonstration of the most promising interventions, and (4) transfer of research results and technologies to industry for implementation and subsequent reduction of bulk materials storage and transport injuries and fatalities.

KEYWORDS: Bulk materials handling, transport, storage, particle flow, hangups, ore pass

BIBLIOGRAPHY

Beus MJ, Iverson S [2000]. New design approaches for mine ore passes based on reduced scale laboratory testing, field experiments, and computer modeling. In: Panagiotou GN, Michalakopoulos TN, eds. Proceedings of the Ninth International Symposium on Mine Planning and Equipment Selection. Rotterdam: Balkema, pp. 15-20.

Beus MJ, Pariseau WG, Stewart M, Iverson SR [2001]. Design of ore passes. Ch. 71 in: Underground Mining Methods - Engineering Fundamentals and International Case Studies. Hustrulid W, Bullock R, eds. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., pp. 627-634.

Underground mines have unique heat sources and limited self-cooling capabilities.

EVALUATION OF HEAT STRESS AND INTERVENTIONS IN SURFACE AND UNDERGROUND MINES

RESEARCHERS: Floyd Varley and Patrick Hintz

AFFILIATION: **Spokane Research Laboratory**
National Institute for
Occupational Safety and Health
(509) 354-8000

PURPOSE: Identify and quantify the sources and levels of exposure of heat in mine environments. Measure the response of workers and evaluate the most promising interventions to reduce effects of heat on miners, focusing on mine equipment design and human factors.

RESEARCH SUMMARY: Previous research by the Mine Safety and Health Administration in 1976 and 1986 identified mine work environments as presenting a significant potential for exposures to heat in excess of the guidelines established in the NIOSH criteria document for this stressor. Since those studies were done, the use of diesel equipment in underground mines has increased, which may have resulted in greater exposure to machine-generated heat. Despite the potential for over-exposure, the incidence of acute heat-related illness is low.

KEYWORDS: Heat stress, stress-related injuries, mining, heat illness, intervention effectiveness, ergonomics, exposure assessment, prevention

Mine operators recognize high heat as an impediment to performance. A corollary assumption is that diminished strength, judgment skills, and safety awareness are related to high heat exposures and would be manifested as increased incident rates. In the NIOSH surveillance report on the mining industry for 1986-95, heat-related illness comprised 12% of all occupational illnesses for sand and gravel operations, peaking in excess of 20% in 1990. The incidence of heat illness at sand and gravel mines has been cyclic, indicating both a relationship to variations in weather conditions and poor adjustment to these changing conditions in the workplace.

The focus of the investigation will be to measure exposure levels concurrently with monitoring miners' responses to their environment in terms of heart rate and core body temperature. Incidence rates of accidents and injuries will be compared to heat exposure measurements to determine if a relationship exists between exposure and risk of injury. Interventions will be selected through a review of current military and industrial practices that might be adaptable to the mining industry in general. Intervention effectiveness will be evaluated by comparing the physiological responses of miners to their work conditions with and without the interventions introduced through this research.

Rear upset test with mannequin.

NEW TECHNOLOGY TO INCREASE ROPS USE ON TRACTORS

RESEARCHER: Timothy J. Lutz

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6648

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

KEYWORDS: Injury prevention, ROPS, tractors, rollovers

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

This is a joint Pittsburgh Research Laboratory/Division of Safety Research safety engineering project that is working on a common problem—too many tractors still do not have ROPS. Innovative ROPS are being designed, developed, and evaluated. During 2000-01, 27 rollover tests were done using a remote-control Ford 4600 agricultural tractor outfitted with various ROPS. The tractor control system had no failures during the testing.

Ten to twenty rollover tests are planned during 2002. The roll sensors and different rollbar configurations are to be tested for reliability, integrity, and shock resistance.

BIBLIOGRAPHY

Lutz TJ, Homce GT [2000]. Remote controls on an agricultural tractor for performing ASAE/SAE field upset tests. In: Proceedings of the American Society of Agricultural Engineers Annual Meeting. St. Joseph, MI: American Society of Agricultural Engineers, paper No. 007004.

Myers JR, Snyder KA [1995]. Roll-over protective structures use and the cost of retrofitting tractors in the United States, 1993. J Agr Saf Health *1*(3): 185-197.

A new NIOSH video will demonstrate proper techniques for bolting roof rock safely.

TRAINING AND EDUCATION

INTERACTIVE TRAINING AND EDUCATIONAL DEVELOPMENT

RESEARCHER: Elaine Cullen

AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000

PURPOSE: Develop safety training tools to teach safe mining practices to a changing mining workforce, particularly new miners who may not have had the opportunity to learn these practices from experienced older miners.

RESEARCH SUMMARY: A NIOSH study on occupational deaths during 1990-99 indicated that, in the mining industry, the average fatality rate was 26 per 100,000 workers. Mining continues to be one of the highest risk industries in the country in spite of significant reductions in fatalities and serious injuries over the past century. With a mining population that is nearing retirement age, it is imperative to develop effective tools to train replacement workers, who may not have the benefit of learning from the experts currently working in the industry.

Video can be used to fulfill several requirements of effective training for miners. SRL has successfully developed a series of training videos that use miners themselves to tell the story. With input from mine safety professionals, topics have been selected to fill gaps in existing training materials. These experts are also used to expand upon topics to include all relevant issues and to ensure that story boards and scripts are technically correct and relevant to trainees. Mine safety professionals and managers have provided access to mine sites, equipment, and miners to tape training segments that are realistic and credible.

Another benefit of using video as a training medium is to capture the wisdom of expert miners before they leave the industry. SRL has taped a series of interviews with experienced miners and has begun the process of gleaning focused safety messages from them. The recently released "Hidden Scars" is an example. This video allows a 34-year veteran to tell his story of the rock burst that killed his partner and left him buried for over 2 hours.

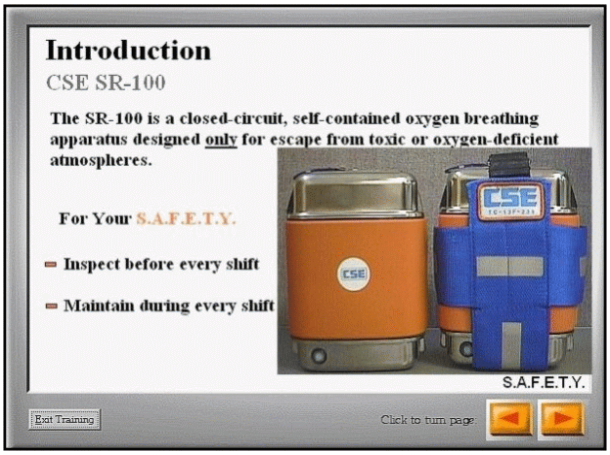
KEYWORDS: Mining, safety training, videos, underground

BIBLIOGRAPHY

Cullen ET, Peppin C [2000]. Miner Mike saves the day—or ground support—it's important. Spokane, WA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Videocassette.

Cullen ET [2001]. Hidden scars. Spokane, WA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Videocassette.

Cullen ET [2001]. Hazards in motion. Spokane, WA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Videocassette.



Screen from the SCSR maintenance and inspection CBT module.

EVALUATION OF INTERACTIVE MINE SAFETY AND HEALTH TRAINING METHODS

RESEARCHER: Michael J. Brnich, Jr.

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6648

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

KEYWORDS: Mining, intervention, training effectiveness

BIBLIOGRAPHY

NIOSH [1999]. A model for research on training effectiveness (TIER). Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-142.

Rethi LL, Barrett EA [2000]. Development and evaluation of a training exercise for construction, maintenance, and repair work activities. In: Bockosh GR, Karmis M, Langton J, McCarter MK, Rowe B, eds. Proceedings of the 31st Annual Institute of Mining Health, Safety and Research. Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, pp. 93-102.

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

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

The beta version of a computer-based training (CBT) exercise for mining called the "Raggs and Curly Machine Guarding Exercise" has been completed. The exercise, which is designed to teach proper machine guarding, is being sent to mine safety trainers for evaluation. Data from mine trainers regarding their use of the CBT module in the classroom are to be collected and summarized. Project staff are preparing two training interventions for field testing that address the NIOSH-identified safety concern of miners who may not be properly maintaining their self-contained self-rescuers (SCSRs). A video training module and CBT exercise were developed for the CSE SR-100. Both modules are being prepared for authentication and field testing. These activities are being coordinated with the NIOSH SCSR initiative.

Another goal is to improve the availability of high-quality training materials. Refinement of the training material distribution system continues. Additional existing training exercises are being converted for Web distribution. A Web-based database is being developed to track the materials. This system has already distributed more than 40,000 training items since January 1999. Currently, 36 training products are posted on the NIOSH Web site for more convenient access.

Toolbox training can provide safety reminders to workers throughout the year as they work around processing plants, pits, and shop areas. This method of training is being evaluated for effectiveness for sand and gravel miners.

EVALUATING TOOLBOX TRAINING FOR CONSTRUCTION AND MINING

RESEARCHERS: C.M.K. Boldt and Floyd Varley

AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000

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

RESEARCH SUMMARY: "Toolbox" or "tailgate" training is a primary mode of occupational safety and health training for workers employed in small construction companies. This type of training consists of short (usually 10 to 15 minutes) weekly sessions conducted on-site prior to work shifts. Toolbox/tailgate training is also used in other sectors of industry, including mining and agriculture. However, the toolbox/tailgate training approach has not been adequately evaluated. In this project, researchers seek to (1) identify and review existing toolbox talks for the construction, mining, and agricultural industries, (2) identify salient characteristics and different types of toolbox training materials, (3) prepare toolbox talks for one high-risk sector in mining (i.e., sand and gravel mining) and one high-risk sector in construction (i.e., residential building), and (4) evaluate the effectiveness of representative existing toolbox talks. Each toolbox talk in the NIOSH series contains a narrative "story" about one or more serious or fatal accidents. This story is based on available injury and fatality investigative reports from NIOSH, the Mine Safety and Health Administration, the Occupational Safety and Health Administration, and other sources. The project, which is being done in collaboration with NIOSH's Division of Safety Research and the Education and Information Division, will investigate whether this narrative material produces the desired results, such as increased knowledge, appropriate changes in attitude, and positive changes in behavior and/or work practices, and how effective the material is.

KEYWORDS: Mining, sand and gravel, training

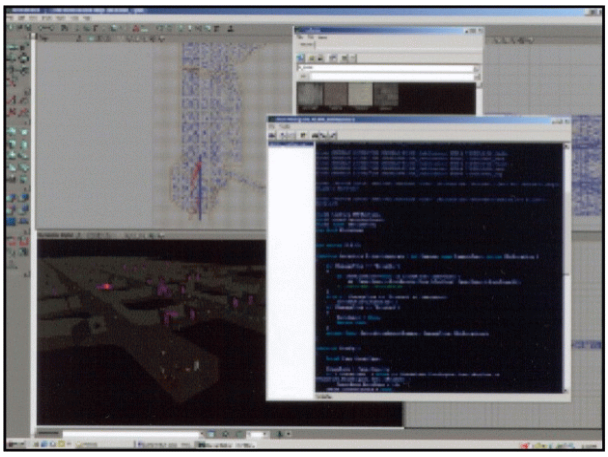
BIBLIOGRAPHY

Boldt CMK, Varley F [2000]. Toolbox training for sand and gravel miners. Presentation at Arizona State Inspector's 10th Annual Mine Safety and Health Seminar, Oct. 3-5, Flagstaff, AZ.

Boldt CMK [2000]. Toolbox safety training for sand and gravel miners. Presentation at NIOSH Open Industry Briefing, Northwest Mining Association annual meeting, Dec. 5, Spokane, WA.

Boldt CMK [2001]. Toolbox training. Presentation at National Holmes Safety and the National Association of State Mine Inspectors Conference, June 5-7, San Antonio, TX.

Varley F [2001]. Toolbox training for sand and gravel miners. Presentation at Western Training Needs seminar, July 25-26, Golden, CO.



The editing program allows the user to customize quickly the virtual environment to achieve specific training goals.

VIRTUAL REALITY FOR MINE SAFETY TRAINING

RESEARCHERS: Timothy Orr and Floyd Varley

AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000

PURPOSE: Take the Virtual Reality Mine Safety Training (VRMST) software developed at SRL and incorporate it into the 8-hour refresher training programs at some operating mines.

KEYWORDS: Virtual reality, computer-based training, mine safety training

RESEARCH SUMMARY: Inadequate or insufficient training is often considered as a root cause for many fatalities in the mining industry. By receiving the proposed virtual reality (VR) training, mine workers will be better prepared to identify and manage hazardous operating conditions. The simulations developed during this project will enhance current training techniques by providing hands-on, accurate interactive training in simulated environments. These simulated training environments will increase worker safety by allowing workers to practice basic job skills involving many hazardous conditions, such as low visibility, unstable ground, or working near mobile equipment. In addition, the results of bad choices and incorrect decisions can be illustrated graphically without actually exposing trainees to danger. The VRMST software also provides network capabilities, which will allow trainees located at different computers to work as a team in hazard recognition and evacuation exercises.

The software can be installed on a mid-range personal computer. The development of the VR scenarios will rely on computer graphics engines developed for the personal computer game industry. These graphics engines are very affordable, widely distributed, and provide rich, complex, and flexible virtual environments that can be tailored to meet the training needs of the mining industry as well as the construction and agricultural industries. The inherent flexibility of this type of simulator will allow easy and rapid updating and modification of the training material. The software will ultimately be distributed via the Internet, which will allow end-users to receive frequent software updates, share user-created scenarios, and participate in on-line, multiuser training.

BIBLIOGRAPHY

Filigenzi MT, Orr TJ, Ruff TM [1999]. Computerized accident reconstruction and training for metal/nonmetal mines. Amer J Ind Med (Suppl 1):116-118.

Filigenzi MT, Orr TJ, Ruff TM [2000]. Virtual reality for mine safety training. Appl Occup Env Hyg *15*(6):465-469.

Orr TJ, Filigenzi MT, Ruff TM [2001]. Hazard recognition: computer-based simulation. In: Jenkins FM, Langton J, McCarter MK, Rowe B, eds. Proceedings of the 13th Annual Institute on Mining Health, Safety and Research. Salt Lake City, UT: University of Utah, pp. 21-28.

Orr TJ, Filigenzi MT, Ruff TM [In press]. Desktop virtual reality miner training simulator. Int J Sur Min Reclam Env.

Mine rescue training exercise in low coal.

MINE RESCUE AND RESPONSE

RESEARCHER: Ronald S. Conti

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

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

RESEARCH SUMMARY: Fires are still too common an occurrence in the mining industry. During 1991-2000, 137 reported fires occurred in underground coal and metal/nonmetal mines in the United States. These resulted in 2 fatalities and 34 injuries (these statistics include the Willow Creek Mine fire and explosion). A significantly higher number of unreportable fires are believed to have also occurred.

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

Preparedness is an essential element of any underground mine's strategic plan in dealing with an unexpected event such as a fire. It is important that the fire be detected in the incipient stage and that well-trained and fully equipped miners respond during that crucial period. Any delay can mean serious injuries and the loss of the mine. A fully implemented fire preparedness and response plan is essential in reducing the probability and seriousness of a mine fire.

A study by the Mines Safety and Health Administration indicated that there are 247 State and company mine rescue teams in the United States (127 coal and 120 metal/nonmetal mine teams) composed of 2,000 rescue team members. These statistics show a drastic decline in the number of teams over the last decade as the number of mines decrease. Very often, rescue teams receive hands-on training during actual emergencies or in simulated mine environments with placards to identify objects and hazards. This dedicated group of miners often place their lives in jeopardy to save others.

Partnerships were established with two coal mines and a State agency to evaluate their mine rescue teams. Data have been collected from six mines in Colorado, Idaho, Illinois, Pennsylvania, South Dakota, and Utah to determine their fire preparedness and response capabilities. Interviews with mine rescue teams, fire brigade members, and the general workforce at Lake Lynn Laboratory and at operating mines were done to determine current strengths and needs. These data were used to develop mine rescue training simulations and technologies for firefighting, exploration, and escape.

A lighted lifeline for emergency responders was developed. The lifeline alleviates tripping and falling problems. The different colored light wires allow the team members to easily find their usual position along the lifeline when exploring in darkness and smoke-filled passageways. An underground coal mine fire preparedness and response checklist was completed and is intended to enhance the safety of mine workers by improving the state of fire preparedness at underground mines. A similar checklist is being developed for metal/nonmetal mines.

BIBLIOGRAPHY

Conti RS [2001]. Responders to underground mine fires. In: Proceedings of the 32st Annual Institute of Mining Health, Safety and Research. Salt Lake City, UT: University of Utah, p. 12.

Conti RS, Chasko LL [2000]. Technologies for today's mine emergency responders. In: Proceedings of the Seventh Annual Conference of The International Emergency Management Society (TIEMS), pp. 105-121.

Conti RS, Chasko LL, Lazzara CP, Braselton G [2000]. An underground coal mine fire preparedness and response checklist: the instrument. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2000-144, IC 9452.

Miners of different ages participate in computer-based training.

EDUCATION AND TRAINING FOR AN EVOLVING MINING WORKFORCE

RESEARCHER: **Charles Vaught, Ph.D.**

AFFILIATION: **Pittsburgh Research Laboratory**
National Institute for
Occupational Safety and Health
(412) 386-6648

KEYWORDS: Mining, training, effectiveness research

PURPOSE: NIOSH stakeholders anticipate the retirement of large numbers of miners from the current workforce. Replacement of those employees will require an influx of new miners. The goal of this project is to institutionalize the use of performance-based training and assessment approaches in the programs developed by mining companies to train their changing workforce.

RESEARCH SUMMARY: The initial step of this research plan was to assess injury profiles for workers at both ends of the age spectrum. Assessment involved conducting a review of available surveillance data, gathering input on injury experiences from various mining personnel, and making on-site observations to determine patterns of desirable and undesirable performances. The next step is to assess age- and experience-related differences in acceptance of various training technologies by collecting information from the workforces at three operations. The third step involves developing and authenticating training materials using those technologies determined to be appropriate based on the study described above. In the fourth step, materials that have been developed are to be pilot tested with mine workforces to determine if they function as intended. Following this pilot test, a field test will be done at several training sites. Evaluation instruments will be used to gather information about four key areas of research interest: (1) demographics, (2) trainer and trainee assessments of the instructional packages, (3) psychometric data, and (4) pre- and post-tests to determine the extent of instructional gain. Conclusions will be based on both quantitative and qualitative analyses and will focus on the impact of program materials and strategies, factors that were critical to their success or failure, and recommendations for future training directions.

BIBLIOGRAPHY

Kowalski KM, Vaught C, Brnich MJ, Mallett LG, Reinke DC, Rethi LL, et al. [2001]. The evolving mining workforce: training issues. In: Proceedings of the 32st Annual Institute of Mining Health, Safety and Research. Salt Lake City, UT: University of Utah.

A miner is tested in the mobile audiometric test unit.

INTERVENTION THROUGH EDUCATION AND TRAINING TO PREVENT HEARING LOSS AMONG MINERS

RESEARCHER: Patricia L. Moisan

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

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

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

The goal of this project is to educate miners regarding hearing conservation procedures and train them to recognize ways that they may assist with the hearing loss prevention process. Site visits are conducted nationwide with a state-of-the-art mobile audiometric test unit. Hearing tests and individual fit-testing of personal hearing protection (i.e., earplugs) are performed on about 2,800 noise-exposed workers. By explaining the results to each individual, the problem becomes a personal one in which the miner has a vested interest. Results of the earplug fit-testing are analyzed and compared to the amount of hearing loss observed to determine whether individuals with a hearing loss are more inclined to achieve a better fit with their earplugs. Additionally, the mobile unit has the capability to show a hearing loss training video or computerized hearing loss demonstration to each participant.

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

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

BIBLIOGRAPHY

Franks JR, Stephenson MR, Merry CJ [1996]. Preventing occupational hearing loss: a practical guide. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 96-110.

Solar-powered repeater station transmitting seismic data from the Stillwater Mine.

GROUND CONTROL

IDENTIFICATION AND CONTROL OF ROCK BURST HAZARDS

RESEARCHERS: Theodore Williams, Jeffrey Whyatt, and Brian White

AFFILIATION: Spokane Research Laboratory
National Institute for Occupational Safety and Health
(509) 354-8000

KEYWORDS: Rock bursts, seismicity, mine safety

PURPOSE: Increase miner safety by monitoring seismic hazards associated with deep underground mines and identifying geologic features that contribute to increased risks of rock bursts.

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 occur, countermeasures have been developed that improve miner safety. However, to be effective, 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. Silicification, which is the alteration of rock by silica-bearing faults emanating from quartz veins, seems to be a marker for significantly increased levels of rock strength, rock brittleness, and in situ stress levels. Appropriate protective measures are also being studied.

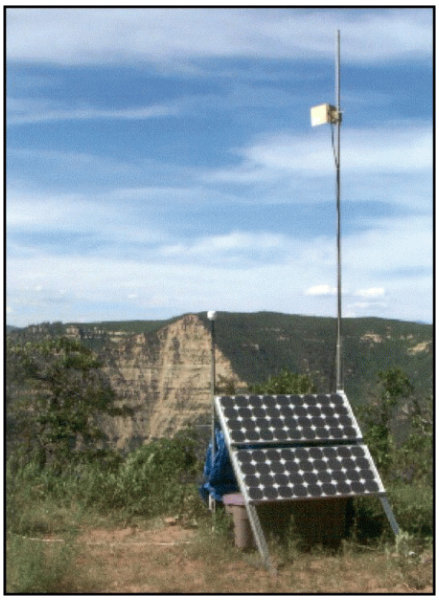
Currently, project studies are focused on mines in the Coeur d'Alene Mining District of northern Idaho and the Stillwater complex of Montana. Seismicity from the Stillwater Mine and the East Boulder Mine is being monitored so that early evaluation of the potential for rock burst problems can be made and measures instituted to reduce miners' risks to rock burst injuries.

BIBLIOGRAPHY

Whyatt JK, Williams TJ, and White BJ [2000]. Ground conditions and the May 13, 1994, rock burst, Coeur d'Alene Mining District, northern Idaho. In: Girard J, Leibman M, Breeds C, Doe T, eds. Proceedings of the Fourth North American Rock Mechanics Symposium. Rotterdam: Balkema, pp. 313-318.

Whyatt JK [2001]. A method for modeling variation of in situ stress related to lithology. In: Elsworth D, Tinnucci JP, Heasley KA, eds. Proceedings of the 38th U.S. Rock Mechanics Symposium. Vol. 2. Rotterdam: Balkema, pp. 1067-1094.

Williams T, Denton D, Seymour JB, Tesarik D, Peppin C, Bayer D [2001]. Interaction between wall rock closure, cemented backfill load and reinforcement bolt load in an underhand stope at the Lucky Friday mine. In: Seventh International Symposium on Mining With Backfill. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.



Wireless network connectivity between remote stations of distributed seismic monitoring system.

GROUND STABILITY ASSESSMENT WITH SEISMIC MONITORING

RESEARCHER: Peter Swanson

AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000

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.

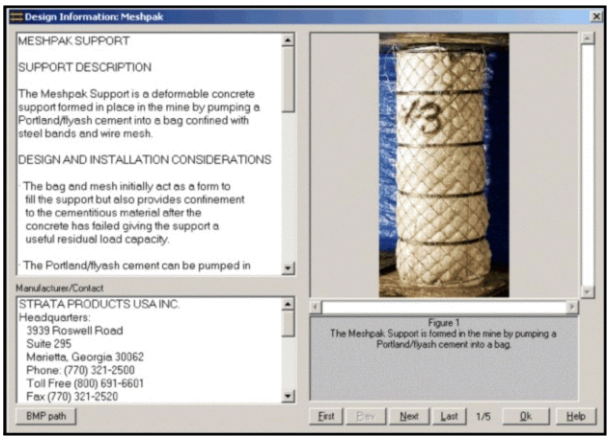
A user-friendly, PC-based, automated seismicity monitoring system has been developed and tested. Various versions of the system have been deployed in both temporary and permanent arrays in hard-rock, coal, limestone, and trona mines in joint efforts with the mining industry. Project research is currently focused on processing and analyzing data collected in these field experiments. These studies include analyses of the locations and failure mechanisms of ground failure events occurring in a deep western longwall coal mine that experienced one of the largest mining-induced seismic events (magnitude 4.2) ever recorded in North America. Seismicity data from this mine will also be used with passive tomographic techniques to examine spatial and temporal changes in the seismic velocity structure. The ability to monitor trends in data reflecting deformation processes from a remote location may allow visualization of stress transfer in the vicinity of work areas and thus provide an additional tool to reduce worker exposure to hazardous ground conditions.

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

BIBLIOGRAPHY

Swanson P [2000]. Automated PC-networked-based seismic monitoring systems applied to mining hazards research. Seismol Res Let *71*(1):234.

Ellenberger J, Heasley K, Swanson P, Mercer J [2001]. Three-dimensional monitoring of a Utah longwall. In: Elsworth D, Tinnucci JP, Heasley KA, eds. Proceedings of the 38th U.S. Rock Mechanics Symposium. Rotterdam: Balkema, pp. 1321-1326.



The Support Technology Optimization Program was introduced at a series of open industry briefings held throughout the country.

DEVELOPMENT AND EVALUATION OF INNOVATIVE ROOF SUPPORT TECHNOLOGIES

RESEARCHER: Thomas M. Barczak

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

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

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

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

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

Seven new roof support systems were tested during the past year. The Support Technology Optimization Program (STOP) was upgraded with several new features. These include (1) use of uncontrolled convergence in the design requirements, (2) addition of new standing support technologies, (3) design procedure for cable bolts, (4) additional performance warnings, and (5) more graphics capabilities.

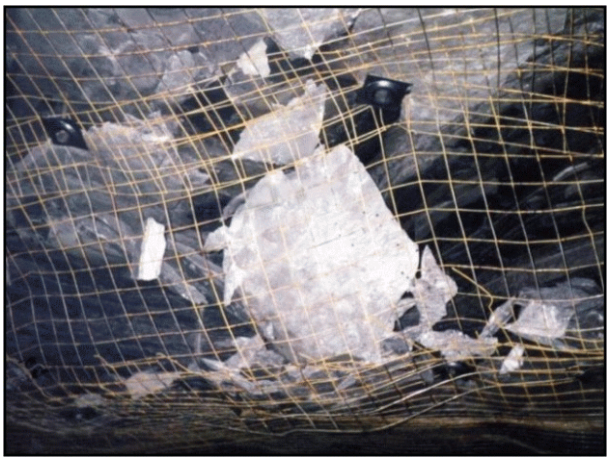
This project began in FY2000 and is expected to continue for at least 4 more years as new support technologies are developed to improve ground control in underground mines.

BIBLIOGRAPHY

Barczak TM [2000]. Optimizing secondary roof support with the NIOSH Support Technology Optimization Program (STOP). In: Peng SS, Mark C, eds. Proceedings of the 19th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 74-83.

Barczak TM [2001]. Updating the NIOSH Support Technology Optimization Program (STOP) with new support technologies and additional design features. In: Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 337-347.

Barczak TM, Mucho TP, Dolinar D, Bower J, Bryja J [1999]. Longwall tailgate support: consideration, design, and experience. In: Proceedings of Longwall USA International Exhibition & Conference, pp. 79-104.



Minor rock fall that occurred between roof bolts and surface control. Here, the surface control provided protection to the mine workers.

PREVENTING INJURIES FROM FALLING ROCK IN UNDERGROUND COAL MINES

RESEARCHERS: Dennis R. Dolinar and Gregory M. Molinda

**AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6648**

KEYWORDS: Underground mining, roof support systems, ground control

PURPOSE: To reduce the risk of injury from minor rock and rib falls by removing the barriers that limit the use of surface control technology. These barriers include a lack of understanding of the geologic conditions that lead to small rock falls, a lack of knowledge about successful surface control techniques, inadequate installation procedures and equipment, lack of engineering design guidelines, impact on production, and costs.

RESEARCH SUMMARY: Each year, about 800 reported injuries, including 3 to 4 fatalities, result from relatively minor falls of rock from the roof or in coal mines. These injuries occur in areas that have been supported and should be safe. Rock fall injuries are quite severe, resulting in an average of 50 lost days for each occurrence. Existing roof supports (roof bolts and automated temporary roof support systems) protect the workers from major collapses, but are not entirely effective in preventing small rock falls.

Various surface control techniques are used in mines to control minor rock falls of the roof and rib. However, current technologies are often ineffective, and they can be expensive and time-consuming to install. As a result, mine operators (particularly small mine operators) are often reluctant to use these technologies. This project is designed to reduce obstacles to the use of surface control and improve the effectiveness of the surface control systems.

The two main tasks at present are the identification of mines and geologic environments that have a high risk of rock and rib falls and the identification of current best practices used for surface control. Ultimately, engineering guidelines for the design and use of surface control systems will be developed. To determine the conditions that may require the use of surface control, a roof rating system has been developed. This rating system can be used to determine if the roof conditions are severe enough to warrant the use of surface control. To evaluate the impact of the installation of surface control on productivity, a time study on roof support installation that included wire mesh was recently completed. Results show that the extra time required to install the mesh was less than the time to install one additional roof bolt per row.

BIBLIOGRAPHY

Bauer ER, Dolinar DR [2000]. Skin failure of roof and rib and support techniques in underground coal mines. In: Mark C, Dolinar DR, Tuchman RJ, Barczak TM, Signer SP, Wopat PF, eds. Proceedings: new technology for coal mine roof support. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2000-151, IC 9453, pp. 99-109.

Tadolini SC, Dolinar DR [2001]. Enhanced surface control for roof and rib. In: Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 173-179.

Microsesmic system at mine site trailer.

REDUCING GROUND FALLS IN UNDERGROUND STONE AND NONMETAL MINES

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

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

PURPOSE: Improve safety and health conditions for mine workers in underground stone and nonmetal mines by developing safety research engineering tools and through communication and surveillance techniques.

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

RESEARCH SUMMARY: Mine workers in underground stone and nonmetal mines continue to be hurt or killed at rates disproportionate to the population compared to the surface segments of these mining industries. The fatality rate for underground stone mines was the highest for all mining both above and below ground, according to the NIOSH *Worker Health Chartbook, 2000*.

This project includes a unique experiment aimed at developing a scientific understanding of stress fields in relation to the direction of mining development. Elevated horizontal stresses can affect large spans of mine roof rock and often result in large roof falls. To determine if a change in mining direction will impact the stability of the roof rock, microseismic monitoring is continuing at a mine in southwestern Pennsylvania. The microseismic system deploys 14 instruments to record "noise" levels of breaking and fracturing rock as mining proceeds in two different directions. It is presumed that collection and analysis of these data will provide scientific evidence to support observational information that changing the direction of mining can result in more stable roof conditions and thus a safer work environment. This experiment is being enhanced by the addition of 8 to 10 more instruments provided by the operator. A large roof fall in July 2001 temporarily delayed installation of the new instruments and required emergency replacement of portions of the system.

Another instrument to determine roof behavior or ground control parameters is the NIOSH-developed Roof Monitoring Safety System (RMSS). The RMSS provides the capability to measure roof movements through insertion into a borehole into the mine roof rock. Two outcomes are the objective of this work. The first is to measure roof movement on a regular basis to track changes in stability and optimally to develop a "signature" of hazardous conditions. The second outcome is qualitative and is based on the assumption that increasing the interest on the part of mine operators and mine workers in roof conditions through use of monitors will lead to a better understanding and awareness of conditions at the mine site.

Another facet of this project includes a study on slope stability at Lake Lynn Laboratory. A large and expanding sinkhole exists at this site. A monitoring system was designed and installed to determine factors causing these ground movements. This information will provide insights into the mechanisms of slope stability and failure and should be applicable to similar problems in the mining industry.

BIBLIOGRAPHY

Iannacchione AT, Marshall TE, Prosser LJ Jr. [2001]. Failure characteristics of roof falls at an underground stone mine in southwestern Pennsylvania. In: Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 119-125.

NIOSH [2000]. Technology news 481: Update—roof monitoring safety system for underground stone mines. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

Loose rock, Daisy Mine, Nevada.

SLOPE STABILITY HAZARD RECOGNITION FOR METAL/ NONMETAL MINES

RESEARCHERS: Ed McHugh, Jami Girard, and Jeff Whyatt

AFFILIATION: Spokane Research Laboratory
National Institute for Occupational Safety and Health
(509) 354-8000

PURPOSE: Minimize hazards associated with unstable mine slopes through research in advanced monitoring methods, geotechnical design, engineering controls, and computer models.

KEYWORDS: Slope stability, slope monitoring, surface mining, bench design, rockfall, ground control

RESEARCH SUMMARY: Surface mines are deeper and steeper than ever before as a result of both economic pressures and land use restraints. Unstable slopes are hazardous for miners who work on or beneath them, and large-scale failures have the potential to cause catastrophic loss of life. Since 1995, 34 miners died in slope failure accidents at surface mines in the United States. These fatalities ranged from individual rocks falling and striking exposed workers to massive highwall failures that buried large-scale mining equipment. Some instability can be expected at any surface mining operation, but it is the unexpected movement of ground that endangers lives and destroys property.

Approaches to reducing the hazards associated with slope failures include—

(1) Compiling information on and evaluating current practices in slope monitoring and warning systems. A handbook is being developed for mining personnel and will include information on the appropriate application and placement of available instruments, as well as the limitations of warning devices.

(2) Using advanced technology for detecting or predicting slope hazards. Such technology includes remote sensing techniques such as hyperspectral imaging, interferometric radar, and photographic change detection. One element of the project is to test the application of imaging spectrometers to help recognize the presence and geometry of mechanically incompetent, clay-rich, altered rock in pit walls. In cooperation with Carnegie Mellon Research Institute, a portable, ground-based imager was tested that proved the concept of simplified hyperspectral imaging for slope characterization. Interferometric radar can be used to detect very small displacements on ground surfaces, including mine slopes. Cooperative work with Brigham Young University will test the application of radar interferometry to mine-slope monitoring and motion alarms. A third technology under study involves the use of digital and video photography for long-term slope monitoring and change detection.

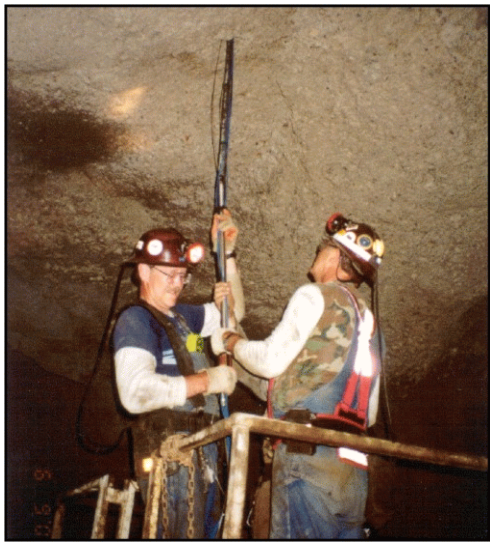
(3) Developing computer programs to assess the performance of catch benches on mine slopes using site-specific data. Benches are designed into mine slopes to catch sliding or rolling slope material and therefore protect miners working downslope. Additional program modules will be developed, and the package will be presented to the mining industry as a tool to aid in safe slope design.

BIBLIOGRAPHY

Girard JM [2001]. Assessing and monitoring open pit mine highwalls. Presentation at the 32nd Annual Institute on Mining Health, Safety and Research, Salt Lake City, UT, Aug. 5-7.

Girard JM, McHugh EL [2001]. Emerging technologies and the future of geotechnical instrumentation in rock mechanics in the national interest. In: Elsworth D, Tinnucci JP, Heasley KA, eds. Proceedings of the 36th U.S. Rock Mechanics Symposium. Vol. 1. Rotterdam: Balkema, pp. 445-450.

McHugh EL, Girard JM, Denes LJ [2001]. Simplified hyperspectral imaging for improved geologic mapping of mine slopes. In: Meech JA, Viega SM, Viega MM, LeClair SR, Maquire JM, eds. Proceedings of the Third International Conference on Intelligent Processing and Manufacturing of Materials (Vancouver, British Columbia, Canada).



Project personnel install a 40-foot-long vertical borehole extensometer in cemented backfill to monitor displacement during mining beneath the backfill.

REDUCING GROUND FALL HAZARDS IN NEVADA UNDERGROUND GOLD MINES

RESEARCHERS: Brian White, Lewis Martin, Brad Seymour, Doug Tesarik, Steve Signer, and Ed McHugh

AFFILIATION: Spokane Research Laboratory National Institute for Occupational Safety and Health (509) 354-8000

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

RESEARCH SUMMARY: The discovery of extensive high-grade gold deposits at depth in Nevada and nearby areas has led to an increase in new underground operations that is likely to continue for decades to come. The large size and irregular shapes of ore zones and the pervasive argillitic alteration and extensive fracturing that characterize these gold deposits make the ground weak and vulnerable to unplanned collapses. Ground failures on all scales are major hazards, with at least one mine reporting five major caves within ore zones and another indicating numerous falls of ground involving failures beyond rock bolt anchorages. From 1990 to 2000, during which employment in underground mines increased tenfold, injuries from falls of ground exceeded those in all other categories in all years except one. Eight fatalities occurred during this period, seven of them since 1995. Nevertheless, Nevada mining companies have substantially adapted to these difficult conditions and have greatly reduced injuries from ground falls. The current project is analyzing the reasons for this success and identifying areas where additional improvement is warranted.

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

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

Interaction between filled and unfilled mine openings and ore and wall rock will be investigated on various scales. Such studies will include elastic, brittle, and time-dependent displacements; their effects on mine openings; and the response of backfill and other ground support to loading.

Fire test of noise control materials in a mining vehicle cab.

CONTROL AND SUPPRESSION OF MINE FIRES

RESEARCHERS: Alex C. Smith and Charles P. Lazzara, Ph.D.

AFFILIATION: Pittsburgh Research Laboratory
National Institute for Occupational Safety and Health
(412) 386-5010

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

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

BIBLIOGRAPHY

Smith AC, Lazzara CP [1998]. Water mist suppression of fires in underground diesel fuel storage areas [Abstract]. In: Beall KA, ed. Annual Conference on Fire Research—Book of Abstracts. Gaithersburg, MD: U.S. Department of Commerce, Technology Administration, National Institute of Standards and Technology, pp. 111-112.

RESEARCH SUMMARY: Although the number of fires and fire injuries is relatively low for underground mining, fires that occur in confined spaces can have 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. Getting out of such vehicles is often awkward and time-consuming, which makes fire protection systems necessary.

The first task of this project evaluates the application of new and improved fire suppression systems to protect underground mine haulageways and stationary equipment. Full-scale experiments are being done in the fire suppression facility at Lake Lynn Laboratory to determine the effectiveness of water mist systems for extinguishing air compressor fires and examine the interaction of the ventilation flow with the dispersion of the extinguishing agent. The second task assesses the flammability hazards of selected noise control materials that are being introduced into the mining environment under realistic, end-use conditions. The results may be applicable to the development of new or modified laboratory-scale fire tests for fire-resistant noise control materials used at 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.

Optical dust probes used to study dust dispersion in the Lake Lynn Experimental Mine.

EXPLOSION HAZARDS REDUCTION

RESEARCHERS: **Kenneth L. Cashdollar, Eric S. Weiss, and Isaac A. Zlochower, Ph.D.**

AFFILIATION: **Pittsburgh Research Laboratory**
National Institute for Occupational Safety and Health
(412) 386-5010

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

RESEARCH SUMMARY: Explosions in coal mines are due to accumulations of methane gas and/or coal dust. The ignition of such flammable materials can develop into a disaster. For example, an explosion at a Utah mine in July 2000 resulted in 2 deaths, and an explosion at an Alabama mine in September 2001 claimed 13 lives. Explosions can be prevented or mitigated by minimizing methane concentrations through ventilation and drainage, adding sufficient rock dust to inert the coal dust, eliminating ignition sources, using passive and active barriers to suppress propagating explosions, and using high-strength seals to prevent gob explosions from propagating into working areas of the mine. Research into the causes and mechanisms of gas and dust explosions is needed to develop techniques and strategies for explosion prevention and suppression in underground mines and in aboveground processing plants. Assistance is also provided to the Mine Safety and Health Administration (MSHA) in the forensic investigation of mine accidents.

Current research includes large-scale coal dust explosion studies at the Lake Lynn Experimental Mine and lab explosion studies in the 20-liter explosibility chamber. As part of these tests, gas and dust samples are collected during and after the explosions. These samples are analyzed to better understand the combustion and inhibition mechanisms. This basic explosion research is done in conjunction with research at university and private labs. Research on frictional ignitions includes experimental studies and surveillance in commercial mines. Experimental research on frictional ignitions includes measurement of the hot-spot temperature and surface area necessary to ignite flammable gases, vapors from oil, and dust mixtures with air.

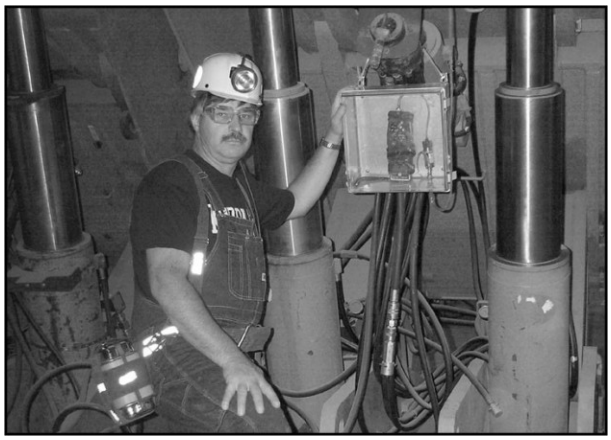
KEYWORDS: Explosions, prevention, mining

BIBLIOGRAPHY

Cashdollar KL [2000]. Overview of dust explosibility characteristics. J Loss Prev Process Ind *13*:183-199.

Cashdollar KL, Zlochower IA, Green GM, Thomas RA, Hertzberg M [2000]. Flammability of methane, propane, and hydrogen gases. J Loss Prev Process Ind *13*:327-340.

Sapko MJ, Weiss ES, Cashdollar KL, Zlochower IA [2000]. Experimental mine and laboratory dust explosion research at NIOSH. J Loss Prev Process Ind *13*:229-242.



A researcher checks a continuous recording methanometer installed on longwall shields at critical locations on the active face during long-term emission studies.

INVESTIGATION OF METHANE CONTROL ISSUES IN UNDERGROUND MINES

RESEARCHERS: William P. Diamond and Steven J. Schatzel

AFFILIATION: Pittsburgh Research Laboratory
National Institute for Occupational Safety and Health
(412) 386-5010

PURPOSE: Investigate existing and evolving methane control issues in coal mines and develop effective control 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: The mining industry's continual implementation of advanced mining technologies sometimes has unexpected consequences. These include increased methane emissions and the associated risk of an explosion or fire in the underground workplace. Methane emission rates are often unpredictable because the interactions between geology, mining, ventilation, and methane control systems vary considerably owing to site-specific conditions and mining practices. The focus of the first phase of this research has been the increase in methane emissions from longwall gobs resulting from emerging technologies that facilitate the mining of increasingly larger dimension longwall panels. Recently completed research resulted in the development of a Longwall Subsided Strata Methane Control Conceptual Model that is the basis for a set of best practices to optimize longwall gob methane control systems. These best practices include optimized placement and operational efficiencies for gob gas ventholes, including a state-of-the-art monitoring and data transmission system based on cellular telephone technology to provide real-time performance data from remote gob gas venthole locations.

The second phase of this continuing research effort, which began in the final year of the predecessor to the current project, focuses on understanding and developing effective control measures for methane emissions originating on extended longwall faces of larger dimension panels and associated continuous miner development sections. These control measures/systems will be integrated with those developed for longwall gob gas control to complete a Comprehensive Longwall Methane Control System/Model and best practices. To reach this goal, current research includes conducting detailed longwall face emission studies at mines operating in the Pittsburgh Coalbed to characterize the geologic and mine design factors influencing methane emissions on the face and in the associated bleeder system. Two such studies have been completed in a mine with relatively low gas emissions. Additional studies will be done at this mine as mining conditions change, as well as at other mines with higher levels of methane emissions. These studies are being done in cooperation with RAG American Coal Co. in close coordination with the United Mine Workers of America, the Pennsylvania Bureau of Deep Mine Safety, and the Mine Safety and Health Administration.

BIBLIOGRAPHY

Diamond WP, Garcia F [1999]. Prediction of longwall methane emissions: an evaluation of the influence of mining practices on gas emissions and methane control systems. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-150, RI 9649.

Diamond WP, Schatzel SJ, Garcia F, Ulery JP [2001]. The modified direct method: a solution for obtaining accurate coal desorption measurements. In: Proceedings of the International Coalbed Methane Symposium. Tuscaloosa, AL: University of Alabama, pp. 331-342.

Mucho TP, Diamond WP, Garcia F, Byars JD, Cario SL [2000]. Implications of recent NIOSH tracer gas studies on bleeder and gob gas ventilation design. SME preprint 00-8. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.

EXTENDED-CUT AIR DELIVERY SYSTEMS

RESEARCHER: Charles D. Taylor

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

Sonic anemometer used for measuring airflow direction and velocity.

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

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

RESEARCH SUMMARY: A full-scale test gallery is used to evaluate the effects of engineering controls on the ventilation of extended-cut mining entries. A sonic anemometer is used to provide airflow velocity and direction information in the entry. With this information, airflow patterns are drawn and compared to determine how engineering controls direct intake air toward the face to dilute and remove the methane gas. Attached to a structure that allows the anemometer to be moved left and right across the entry, toward and away from the entry face, and up and down within the entry, the instrument can be precisely positioned at the desired monitoring locations.

Machine-mounted water sprays and scrubbers are two valuable techniques for improving intake airflow to the face during extended-cut mining. Gallery studies showed that, with blowing ventilation, the combined use of the scrubber and sprays can further reduce methane levels if the sprays are directed to move air from the intake to the return side of the face. The direction of the scrubber exhaust also had a large effect on intake flow to the face. Directing the exhaust flow straight back toward the return increased intake flow to the face. When the blowing curtain was outby the rear of the mining machine, directing the scrubber exhaust toward the intake side of the entry reduced the amount of intake air reaching the face.

The effectiveness of engineering controls for controlling methane levels and compliance with Federal regulations can be ensured only if methane levels are accurately monitored. Studies have been conducted to determine how methanometer sampling location and sensor head design affect the accuracy of face methane readings. Recent studies were done to provide guidelines for locating instruments on the mining machine. Studies are now being conducted to determine how instrument design affects the time required for a methanometer to respond to changes in gas concentrations. Criteria for measuring response times, as well as procedures for making these measurements underground, are being evaluated.

BIBLIOGRAPHY

Taylor CD, Zimmer JA [2001]. Effects of water sprays used with a machine-mounted scrubber on face methane concentrations. SME preprint 01-114. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.

Taylor CD, Thimons ED, Zimmer JA [2001]. Factors affecting the location of methanometers on mining equipment. In: Proceedings of the Seventh International Mine Ventilation Congress (Krakow, Poland), pp. 683-688.

Handheld ultrasonic anemometer capable of measuring very low air velocities.

VENTILATION OF LARGE-OPENING MINES

RESEARCHER: Robert J. Timko

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6683

KEYWORDS: Mine ventilation, metal/nonmetal mines, large openings, anemometry, ultrasonic, air velocity

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

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

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

This project is evaluating methods to measure very low air flows in large-opening mines. The traditional tool for measuring air movement is the vane anemometer. Because of the large cross-sectional entry area, it is impossible to measure the air velocity using a vane anemometer and simply performing a moving traverse of the entry. To overcome this, researchers are determining how the entry area can be divided most effectively to provide a more accurate estimate of actual entry air volume. Ultrasonic anemometry, a technique that seems to be able to measure very low air velocities, is being used to measure the entry air flow.

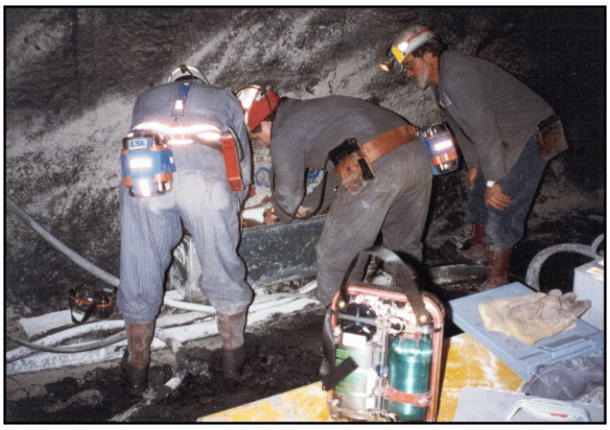
A current problem is that, even when low air velocities are measured, there is no method available to ensure that the devices measuring the air are properly calibrated. MSHA measures air velocities down to 100 feet per minute. Minimum velocities measured at the National Institute of Standards and Technology approach 30 feet per minute. NIOSH results often are less than 10 feet per minute. NIOSH researchers are building a device that can calibrate instruments that measure very low air flows. This device uses a novel technology that will enhance the ability to accurately measure low velocities.

BIBLIOGRAPHY

Hartman HL, Mutmansky JM, Ramani RV, Wang YJ [1997]. Mine ventilation and air conditioning. 3rd ed. New York, NY: John Wiley & Sons, Inc.

Kohler JL, Thimons ED [1987]. An analysis of air volume-flowrate determinations for mines. Min Sci Technol *6*(1):17-29.

Thimons ED, Brechtel CE, Adam ME, Agapito JFT [1986]. Performance characteristics of large-capacity face ventilation systems for oil shale mining. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, RI 9006.



Collecting SCSRs for a long-term field evaluation study.

LIFE SUPPORT FOR SURVIVAL AND RESCUE

RESEARCHER: John G. Kovac

AFFILIATION: National Personal Protective Technology Laboratory
National Institute for Occupational Safety and Health
(412) 386-6544

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

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

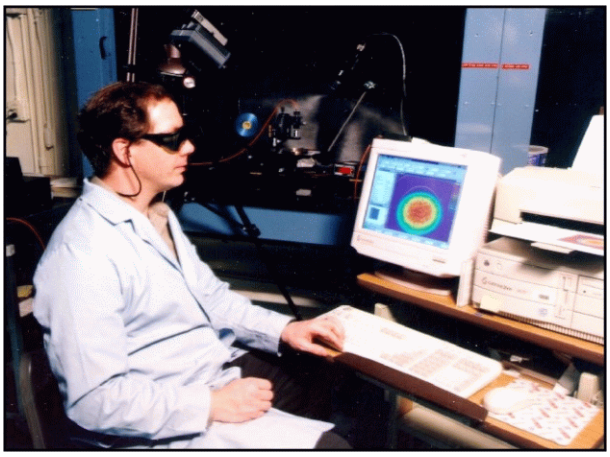
BIBLIOGRAPHY

Kyriazi N, Shubilla JP [1999]. Self-contained self-rescuer field evaluation: sixth-phase results. Pittsburgh, PA: U.S. Department of Health and human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2000-128, IC 9451.

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

NIOSH is conducting a long-term evaluation of SCSRs deployed in underground coal mines. Mine operators are located that are willing to participate in the study, deployed SCSRs are exchanged for new ones, and then the deployed SCSRs are tested. The goal of this 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.

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



A researcher measures laser beam parameters with a beam-profiling camera system.

LASER SAFETY IN POTENTIALLY FLAMMABLE ENVIRONMENTS

RESEARCHER: Thomas H. Dubaniewicz, Jr.

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-6648

PURPOSE: Determine powers, diameters, and durations required for optical beams to be considered a potential ignition source in flammable environments found in mining and other industries.

KEYWORDS: Injury prevention, explosions, dust

RESEARCH SUMMARY: This project supports the National Occupational Research Agenda traumatic injuries research area. Emerging laser technologies are quickly gaining acceptance in industrial applications. Laser-based instruments monitor levels of coal and grain processed in the mining and agriculture industries, respectively. Fiber-optic communication systems are routed through rights of way, such as sewer systems and pipelines containing natural gas. Chemical plants are using powerful laser-based Raman-backscatter instruments to monitor flammable material processes. The conditions under which a laser beam may be considered a potential ignition source in many of these environments are not well known.

Experimental research is being done using a 20-liter test chamber in which flammable dusts and gases are studied. These include Powder River Basin coal dust, Pittsburgh coal dust, grain dust, lycopodium, methane, and several other hydrocarbon gases. Igniting power thresholds for each flammable material are recorded as a function of laser beam diameter and concentration of the flammable material in air. The time needed to ignite a material after initial laser exposure, or ignition delay time, is also recorded. The knowledge gained will help to develop explosion prevention engineering controls. For example, fiber-optic system designers can use the ignition time delay information to build automatic shutoffs that initiate quickly enough to prevent ignitions in case of accidental fiber breakage or disconnect.

A means to prevent incidental ignitions of hazardous gassy atmospheres by lasers is being investigated through infrared thermography. The temperatures of surfaces absorbing optical energy from a laser are monitored. When such temperatures exceed predefined safe levels, the laser power source is deenergized to prevent incidental ignitions.

Recommendations from this work are expected to impact consensus and statutory safety standards, such as the American National Standards Institute (ANSI) Z136 series laser standards; Instrumentation, Systems, and Automation Society hazardous location standards; and International Electrotechnical Commission (IEC) standards.

BIBLIOGRAPHY

Dubaniewicz TH Jr., Cashdollar KL, Green GM, Chaiken RF [2000]. Ignition of methane-air mixtures by laser-heated small particles. J Loss Prev Process Ind *13*:349-359.

Welzel MM, Schenk S, Hau M, Cammenga HK, Bothe H [2000]. Ignition of combustible/air mixtures by small radiatively heated surfaces. J Hazard Mater A72:1-9.

Gas samples are taken from a borehole near a blasting site.

SURFACE BLASTING SAFETY AND HEALTH

RESEARCHER: Marcia L. Harris

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

PURPOSE: Protect miners from hazards associated with blasting at surface operations involving coal, metal, and nonmetal mining.

KEYWORDS: Blasting, explosives, flyrock, mining

BIBLIOGRAPHY

Rehak TR, Bajpayee TS, Mowrey GL, Ingram DK [2001]. Flyrock issues in blasting. In: Proceedings of the 27th Annual Conference on Explosives and Blasting Technique. Vol. I. Cleveland, OH: International Society of Explosives Engineers, pp. 165-175.

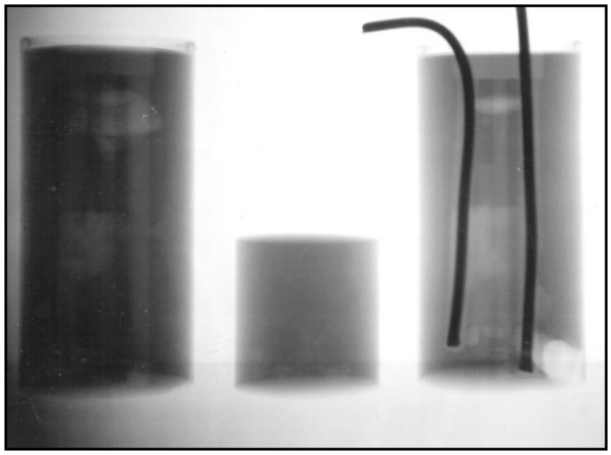
Rowland JH III, Mainiero RJ, Hurd DA Jr. [2001]. Factors affecting fumes production of an emulsion and ANFO/emulsion blends. In: Proceedings of the 27th Annual Conference on Explosives and Blasting Technique. Vol. II. Cleveland, OH: International Society of Explosives Engineers, pp. 133-141.

RESEARCH SUMMARY: The use of explosives near housing developments has increased in recent years. To prevent flyrock that can damage homes or nearby businesses, the blaster ensures that the blast is well confined, i.e., the ground barely moves as it is blasted. However, this provides no way to release the blasting fumes. Thus, the fumes stay in the ground and may travel underground to nearby homes and other confined spaces. The composition of these fumes typically includes carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), and ammonia (NH_3). Over the past 10 years, there have been at least six known incidents of toxic fumes migration into homes and other confined spaces. These resulted in several hospitalizations and one fatality. Research will be done on the migration of CO and other toxic fumes from blast sites to provide blasters with guidelines for protecting workers and nearby residents from fumes poisoning.

Flyrock and lack of blast area security accounts for most blasting-related injuries and fatalities in surface mining. During FY01, flyrock and blast area security issues in the mining industry were reviewed and reported. During FY02, this review will be extended to the construction industry. A training video detailing the hazards due to flyrock and lack of blast area security is to be prepared in cooperation with industry.

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

This project is an extension and expansion of research that was formerly carried out under two projects: "Investigation of Flyrock Injuries and Fatalities" and "Toxic Fumes From Blasting."



X-rays of explosive boosters are used to identify internal components.

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

RESEARCHER: Cynthia A. Mytrysak

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

PURPOSE: Provide technical assistance to the Mine Safety and Health Administration (MSHA) in ensuring the safety of explosives in mining.

KEYWORDS: Permissible, explosive, blasting

BIBLIOGRAPHY

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

RESEARCH SUMMARY: The tasks of this project are to assist MSHA in explosives accident investigations, including the testing of explosives involved in accidents, and 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 from the use of explosives in mining.

Based on an MSHA request, a permissible explosive was submitted for testing. This explosive was previously tested and approved for use. However, the manufacturer was proposing modification of the packaging—from waxed paper to plastic wrapping. Physical examinations and detonation velocity tests were done on the explosive cartridges, and the results were reported to MSHA.

Research was completed on a detonator/booster assembly that was involved in a recent fatal incident and reported to MSHA. Indications were that the detonator/booster assembly fell into a borehole and exploded prematurely when it hit another booster already in the hole. This same detonator/booster assembly had been involved in two other incidents, one of which was fatal. Cooperative research is continuing to find reliable, practical ways to prevent future accidents.

Another request by MSHA was to examine boosters involved in an incident that created an unusual situation. The shot blast was fired, but not all of the holes in the blast pattern fired at the same time. In fact, one hole fired about 45 minutes after it should have. A visual inspection of a broken booster that was received from the incident site revealed black specks of an unknown material and what seemed to be an air pocket. The booster was analyzed to verify the chemical composition and identify the black material. The analysis verified the chemical composition, but the black specks were not identifiable because of the minute quantity. The x-rays of the boosters revealed air pockets. Consultation with an expert on commercial boosters revealed that air pockets are not unusual and do not indicate a hazardous product. In summary, the study identified no obvious hazards associated with the boosters.

Installing load cells in a ventilation stopping in a longwall headgate to measure load development.

IMPROVING CFR SAFETY EVALUATIONS FOR MINE VENTILATION SEALS AND STOPPINGS

RESEARCHER: Thomas M. Barczak

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

PURPOSE: Provide a safer environment and reduce material handling injuries for mine workers by developing alternative safety evaluation requirements and design guidelines for mine ventilation stoppings and seals.

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

RESEARCH SUMMARY: Preparations for lab studies of loading characteristics of stoppings have been completed, but the studies have been delayed due to unavailability of the mine roof simulator. These studies, including transverse loading testings consistent with current Federal requirements, are expected to resume next year.

The major thrust of the project during the past year was an underground case study comparing stoppings constructed from conventional masonry block and lightweight cellular concrete blocks. The study was done in cooperation with CONSOL Energy. Two walls of each construction were instrumented with load cells and displacement transducers to measure load and deflection of the stoppings. The study was conducted in a longwall headgate where cutter roof had developed and provided valuable information on the in situ structural loading mechanisms and how stoppings interact with ground conditions. The study confirmed that conventional stoppings can provide substantial resistance to roof movements depending on the strength of the material used in the stopping construction and raised questions regarding the use of soft inclusions to reduce the stiffness of the structure in an effort to prevent premature failure. In some instances, such as floor heave, a soft inclusion may increase the longevity of a stopping. However, it is possible in other instances that it may allow convergence that leads to accelerated roof loading, which may cause failure of the stopping unless additional roof support is used.

The study also confirmed that preloading can play an important role in determining the lateral or transverse strength of the stopping, which is particularly important since criteria for this are specified in the Code of Federal Regulations (CFR). This issue will be carefully examined in mine roof simulator studies. It is also apparent from the field study that loadings that can cause failure of stoppings can be localized even within the stopping itself. In this case study, the cutter roof caused most of the damage to the stoppings, with relatively little damage in areas where the cutter roof did not occur.

It is clear from this study that stopping design must consider ground movement. Failure of stoppings are more likely to occur from ground movement than from air pressure differentials. As seen in this study, stoppings must be designed to either prevent ground movements or deform with them in order to maintain the required structural integrity and allow the stopping to act as a ventilation control structure.

BIBLIOGRAPHY

ASTM [2001]. Standard test methods of conducting strength tests of panels for building construction. In: E72-98 Annual Book of ASTM Standards: Volume 04.11, Building Constructions. West Conshohocken, PA: American Society for Testing and Materials, pp. 1-11.

Oyler DC, Hasenfus GJ, Molinda GM [2001]. Load and deflection response of ventilation stoppings to longwall abutment loading: a case study. In: Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 34-42.

Remains of a cementitious seal after a methane air explosion.

HYDROSTATIC EVALUATION OF MINE SEALS

RESEARCHERS: **Michael J. Sapko and Eric S. Weiss**

AFFILIATION: **Pittsburgh Research Laboratory**
National Institute for Occupational Safety and Health
(412) 386-5010

KEYWORDS: Mine ventilation seals, water inundation, explosions

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

RESEARCH SUMMARY: Seals are used extensively in mining to isolate worked-out areas of a mine, contain active fire zones, and control water inundations, thereby protecting miners from these life-threatening hazards. Seals, along with generalized rock dusting, are the last line of defense against underground explosions in U.S. coal mines. MSHA has a compelling need to evaluate geometric scaling criteria for seals, alternative designs for high-convergence conditions, and adverse geologic conditions, such as friable adjacent strata. No single seal design is suitable for all possible scenarios. Some seals must withstand excessive convergence, some require quick curing, some require special anchoring because of the adjacent strata conditions, some need to resist attack by acid mine water, some are needed for very wide or high roadways, some need to hold back water, some need steel reinforcement and high-strength cement, some need fire traps, some need a low gas leakage rate, and some must perform for years.

Studies continue to evaluate seals of different cross-sectional areas with pressurized water. Cost-sharing continues with important collaboration between NIOSH, the mining industry, and seal manufacturers. Results from such tests provide valuable information applicable to the on-site evaluation of new mine seals, the development of size-scaling relationships, and design safety factors.

BIBLIOGRAPHY

Sapko MJ, Weiss ES, Cashdollar KL, Greninger NB [1999]. Overview of NIOSH's mine seal research. In: Proceedings of the 28th International Conference of Safety in Mines Research Institutes (Sinaia, Romania). Vol. I, pp. 71-85.

Sapko MJ, Weiss ES, Greninger NB [1999]. Recent mine seal research conducted by NIOSH. In: Sealbarr '99 - Proceedings of the Polish-American Seminar on Seals and Barriers as a Means of Protection Against Fires and Explosions in Mines (Katowice, Poland, May 27-28, 1999), pp. 39-53.

Shaft facility and fan house damaged by an underground mine explosion, Loveridge Mine, Marion County, WV. ***(Photo courtesy of MSHA.)***

REMOTE CONSTRUCTION OF SEALS FOR MINE FIRE CONTROL AND ABATEMENT

RESEARCHER: Michael A. Trevits

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

PURPOSE: Improve and/or modify the state of the art for building remote mine seals for mine fire control and abatement.

RESEARCH SUMMARY: When a mine fire breaks out, all underground mine workers are simultaneously exposed to dangerous conditions. A mine fire can be especially perilous because the toxic fire products can rapidly spread well beyond the fire zone via the mine ventilation system. The most direct firefighting approach involves the application of water, foam, chemicals, gases, rock dust, or sand to the fire zone. Unfortunately, this approach also places miners close to the fire and can quickly expose them to the deadly hazards.

KEYWORDS: Underground mining, fires, seals, drilling

An indirect control and extinguishment approach is used when access to the fire zone cannot be obtained because of a limited supply of available firefighting materials, when a fire zone is too large for available underground personnel, or when blocked underground access or other conditions exist that might lead to a mine explosion. This approach involves installing mine seals to limit the inflow of oxygen and enclose the fire zone. Mine seals can be built underground using various methods or remotely from the surface through vertical boreholes. The process is followed by flooding the affected area with inert gas, silt, or other material to control and extinguish the fire. Installing seals underground is particularly dangerous because miners are exposed to roof falls from heat and fire, potential gas explosions, and asphyxiating gases. The most effective solution when underground access is impossible or too dangerous is to build airtight mine seals in the area of the fire, remotely through vertical boreholes. In theory, this method has great merit because seals can be positioned close to the fire zone without exposing miners to the hazards. However, because this technology is applied blindly through boreholes, it is difficult or impossible, given the current state of the art to construct effective seals.

A technology review has been completed. Contract specifications for remote construction of a mine seal were developed, and a contract was awarded in late FY01. In FY02, at least one mine seal will be built, evaluated, and tested at Lake Lynn Laboratory. A field demonstration at an underground mine site is also scheduled for late FY02. The Mine Safety and Health Administration (MSHA) is a key partner in this research. It is supplying engineering expertise and funds for the field demonstration.

Aerial view of Lake Lynn Laboratory.

LAKE LYNN LABORATORY

RESEARCHER: Eric S. Weiss

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-5010

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.

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

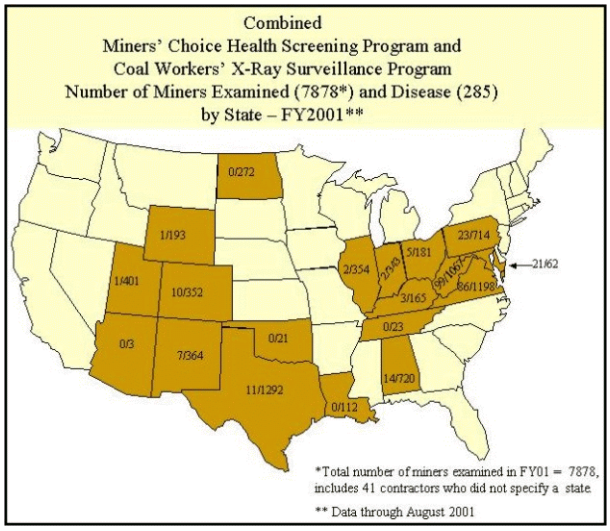
BIBLIOGRAPHY

Mattes RH, Bacho A, Wade LV [1983]. Lake Lynn Laboratory: construction, physical description, and capability. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, IC 8911.

Triebsch G, Sapko MJ [1990]. Lake Lynn Laboratory: a state-of-the-art mining research laboratory. In: Proceedings of the International Symposium on Unique Underground Structures. Golden, CO: Colorado School of Mines, Vol. 2, pp. 75-1 to 75-21.

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

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



Number of miners examined and disease by State.

SURVEILLANCE

COAL WORKERS' HEALTH SURVEILLANCE PROGRAM

RESEARCHER: **Edward L. Petsonk, M.D.**

AFFILIATION: **Division of Respiratory Disease Studies**
National Institute for Occupational Safety and Health
(304) 285-5724

KEYWORDS: Coal Workers' X-ray Surveillance Program, CWXSP, pneumoconiosis, x-ray, coal miners, surveillance, B Readers

PURPOSE: The Division of Respiratory Disease Studies administers the mandates of 42 CFR 37 relating to the National Coal Workers' X-ray Surveillance Program (CWXSP) and maintains a national database for coal workers' pneumoconiosis.

RESEARCH SUMMARY: This project administers the underground coal miner x-ray surveillance activities as specified in 42 CFR 37 and maintains a database that is used by researchers involved in developing strategies to prevent or reduce the incidence and progression of coal workers' pneumoconiosis. This program includes the certification of x-ray facilities; the training, testing, and certification of physician readers (B Readers); the interpretation of films; the communication of results to miners, their personal physicians, and the Mine Safety and Health Administration (MSHA); the notification of miners of options to transfer to low dust areas; and the provision of data to evaluate the respiratory health of underground coal miners. It supports the implementation of the U.S. Department of Labor Dust Advisory Committee's recommendations and MSHA regulatory activities, as required.

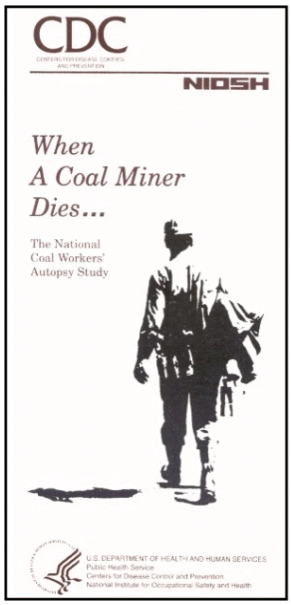
NIOSH and MSHA have entered into an interagency agreement to improve miner participation in this program by targeting surface and underground miners at specific mines. Each miner at these specific mines is given the opportunity to have a free chest x-ray. For surface miners, MSHA pays for the x-ray, as well as the interpretation and related costs. NIOSH continues its support of the CWXSP. From October 2000 to August 2001, 7,878 miners were x-rayed under these programs. Of these, 3,686 were surface miners and 1,764 were underground miners participating in the Miners' Choice Health Screening Program. The remainder were underground miners participating in the CWXSP. Definite evidence of pneumoconiosis was found in 86 (2.3%) of the surface miners and 199 (4.8%) of the underground miners. This emphasizes the success of the Miners' Choice Health Screening Program in detecting pneumoconiosis in previously unscreened surface miners, as well as in increasing overall participation in the CWXSP.

BIBLIOGRAPHY

Wagner GR, Attfield MD, Kennedy RD, Parker JE [1992]. The NIOSH B reader certification program: an update report. J Occup Med *34*(9):879-884.

Wagner GR, Attfield MD, Parker JE [1993]. Efforts to improve consistency and accuracy in chest radiographic classification in the United States: the NIOSH B reader program. In: Proceedings of the ILO Eighth International Conference on Occupational Lung Diseases (Prague), pp. 827-832.

Wang ML, Petsonk EL, Wagner GR [2001]. Pneumoconiosis prevalence among working U.S. coal miners: preliminary results based on chest x-ray screening data, 1995 to 2000 [Abstract]. Am J Epidem *153*(Suppl):11:S127.



NIOSH flyer describing the NCWAS.

NATIONAL COAL WORKERS' AUTOPSY STUDY

RESEARCHER: **Edward L. Petsonk, M.D.**

AFFILIATION: **Division of Respiratory Disease Studies**
National Institute for Occupational Safety and Health
(304) 285-5726

PURPOSE: This project responds specifically to the mandates in 42 CFR 37 and is responsible for administering the National Coal Workers' Autopsy Study (NCWAS). Specimens reviewed as a result of this program are used to evaluate effectiveness of dust exposure levels in underground coal mines.

RESEARCH SUMMARY: This project administers the mandates of 42 CFR 37 through receipt and evaluation of autopsy cases submitted by pathologists participating in the NCWAS. The NCWAS is a service benefit to survivors of coal miners. The results of the autopsy (1) provide medical evidence in support of black lung benefit claims, (2) assist in conducting research into the epidemiology, pathogenesis, and prevention of coal workers' pneumoconiosis and silicosis, and (3) provide forensic assistance in the investigation of coal mine fatalities. This project is conducted in cooperation with the United Mine Workers of America and the Mine Safety and Health Administration.

KEYWORDS: National Coal Workers' Autopsy Study, NCWAS, autopsy, coal workers' pneumoconiosis, silicosis, coal miners

BIBLIOGRAPHY

Green FHY, Althouse R, Frost JL, Wheeler RW, Shores SK [1986]. Forensic investigation of coal mine fatalities. Ann Am Conf Gov Ind Hyg *14*:117-124.

Green FHY, Althouse R, Parker J, Kahn J, Weber K, Vallyathan V [1998]. Trends in the prevalence of coal workers' pneumoconiosis in US autopsied coal miners. In: Proceedings of the Ninth International Conference on Occupational Respiratory Diseases (Kyoto, Japan). Elsevier, pp. 145-148.

Green FHY, Althouse R, Weber KC [1989]. Prevalence of silicosis at death in under-round coal miners. Am J Ind Med *16*:605-615.

A miner undergoes lung function testing.

AIRWAYS DISEASE IN MINERS

RESEARCHERS: Lu Ann Beeckman-Wagner, Ph.D., and Edward L. Petsonk, M.D.

AFFILIATION: Division of Respiratory Disease Studies
National Institute for Occupational Safety and Health
(304) 285-5792

KEYWORDS: FEV_1, underground coal miners, lung function

PURPOSE: A quantitative relationship between coal mining exposures and lung function loss has been repeatedly demonstrated. However, after accounting for the effects of smoking and dust exposure, it is still not understood why some miners suffer severe FEV_1 declines. The goals of this project include (1) describing the health consequences of the excessive loss in lung function observed in some miners, (2) identifying potential environmental and constitutional risk factors for adverse ventilatory responses to dust, (3) defining disease processes and mechanisms that lead to an accelerated loss of lung function, and (4) evaluating methods for investigating lung function changes in relation to occupational exposures to improve future studies.

RESEARCH SUMMARY: Researchers determined vital status for 561 underground coal miners and obtained an extensive novel followup questionnaire for 121 miners with severe losses in lung function (cases) and 143 miners with relatively stable lung function (referents). Miners (or their next of kin, if deceased) were contacted by phone and asked extensively about specific job activities and working conditions, non-work-related exposures, living conditions, and personal smoking and health histories. The lung function of all of the study miners had been followed for an average of 11 years. Associations were evaluated between various candidate risk factors and clinically important FEV_1 loss. Several mine environment variables, as well as recognized effects of mining tenure and region, were found to be associated with excess FEV_1 decline. These included work in roof bolting, exposure to explosive blasting, and use of water for dust control sprays that had been stored in holding tanks. Use of respiratory protection seemed to reduce the risk of FEV_1 loss. More cases than referents (15% versus 4%) left mining prior to retirement because of chest illnesses. Case miners showed a higher incidence than referents of respiratory symptoms, asthma, and emphysema. They also had twice the risk of dying with cardiovascular and nonmalignant respiratory diseases and a 3.2-fold risk of dying with chronic obstructive pulmonary disease. Based on a sophisticated analysis of longitudinal lung function tests in coal miners, tables have been published that should be useful for future occupational studies in ensuring that these studies will obtain acceptable values of maximum error and adequate power to detect anticipated differences in FEV_1 slopes between study groups.

BIBLIOGRAPHY

Beeckman LA, Wang ML, Petsonk EL, Wagner GR [2001]. Accelerated declines in FEV_1 and subsequent increased respiratory symptoms, illnesses, and mortality in U.S. coal miners. Am J Resp Crit Care Med *163*:633-639.

Wang ML, Gunel E, Petsonk EL [2000]. Design strategies for longitudinal spirometry studies: study duration and measurement frequency. Am J Resp Crit Care Med *162*:2134-2138.

Wang ML, Petsonk EL, Beeckman LA, Wagner GR [1999]. Clinically important FEV_1 declines among coal miners: an exploration of previously unrecognized determinants. Occup Env Med *56*:837-844.

Diesel equipment in a salt mine.

A COHORT MORTALITY STUDY WITH A NESTED CASE CONTROL STUDY OF LUNG CANCER AND DIESEL EXHAUST AMONG NONMETAL MINERS

RESEARCHER: Michael D. Attfield, Ph.D.

AFFILIATION: Division of Respiratory Disease Studies
National Institute for Occupational Safety and Health
(304) 285-2817

KEYWORDS: Diesel, mining, mortality

BIBLIOGRAPHY

Bhatia R, Lopipero P, Smith AH [1998]. Diesel exhaust exposure and lung cancer. Epidemiology *9*:84-91.

Haney RA, Saseen GP, Waytulonis RW [1997]. An overview of diesel particulate exposures and control technology in the U.S. mining industry. Appl Occup Env Hyg *12*(12):1013-1018.

PURPOSE: Evaluate mortality from lung cancer and other diseases among nonmetal miners in relation to extent of exposure to quantitative measures of exposure to diesel exhaust using a cohort and nested case control study.

RESEARCH SUMMARY: Diesel exhaust is a commonly occurring airborne contaminant. Exposure is frequent, both environmentally and occupationally. Occupational exposures can be intense. Although diesel exhaust has been classified as a probable carcinogen by the International Agency for Research on Cancer and as a potential carcinogen by NIOSH, the risk of lung cancer in humans is not well defined. In particular, although more than 30 studies have examined lung cancer risk and diesel exhaust exposure, few have used quantitative exposure measurements of diesel exhaust directly in their analyses.

To obtain further information on this important question, NIOSH is undertaking a full-scale mortality study of health outcomes associated with exposure to diesel exhaust. It consists of a retrospective cohort mortality study with a nested case control study of lung cancer. An extensive effort is being made to characterize current and past levels of surrogates of diesel exhaust with the aim of developing reliable estimates of cumulative exposure and associated indices. These exposures will be used to investigate exposure-response in the two studies.

The study is being done on nonmetal mine workers. Nonmetal mines were chosen because exposures to potential confounders such as radon, silica, arsenic, and asbestos are few and at low levels. Furthermore, exposures in many of the mines have been substantial in the past, and there exist databases of prior exposure levels, which facilitates development of past exposure estimates. Lastly, the mines are generally large and involve workers both underground and on the surface. This provides a wide range of exposures and thus sufficient power to detect any possible effects of exposure. There are 10 mines in the study (4 potash, 3 trona, 2 salt, and 1 low-silica limestone). These were chosen through evaluation following an extensive pilot trial.

The work involves five parts: (1) characterization of current exposure levels by means of a thorough industrial hygiene survey at each operating mine; (2) development of retrospective exposure estimates using the results from the first part and using all relevant past data, including measurements and surrogates; (3) acquisition of personnel records required to define a

retrospective cohort from date of dieselization to the present at each mine, followed by vital status followup ascertainment; (4) a cohort mortality analysis using the results from the current and retrospective exposure assessment components to examine excesses in mortality compared to external rates and internal comparisons based on job, tenure, and quantitative exposure estimates; and (5) a case control study of lung cancer based on the deaths identified from the cohort study and using the exposure estimates from the current and retrospective exposure assessment components enhanced by additional information obtained for the case control study subjects.

Data collection for the project began around December 1997. The planned schedule for the project outlined in the study protocol calls for completion in 6 years. Much of the data collection is complete for the exposure derivation and the cohort mortality followup. Ongoing activities are largely focused on data analysis and information collection for the case control study.

RISK FACTORS FOR ATHEROSCLEROSIS AMONG COAL MINERS

RESEARCHER: Deborah D. Landen, M.D.

AFFILIATION: Pittsburgh Research Laboratory
National Institute for Occupational Safety and Health
(412) 386-4207

KEYWORDS: Cardiovascular disease, stress, coal mine dust

PURPOSE: Determine the prevalence of risk factors for atherosclerosis among a sample of coal miners and the relationship between risk factors and workplace exposures.

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

This goal of this study is to determine the prevalence of risk factors for atherosclerotic disease among a sample of coal miners. The ratio of blood pressure in the arm to blood pressure at the ankle, the ankle-arm index, will be obtained as an indicator of atherosclerosis. The association between risk factors for coronary heart disease, ankle-arm index, and workplace exposures to both work-related stress and coal dust will be examined. NIOSH is cooperating with the United Mine Workers of America (UMWA) on this project, which will be conducted among UMWA miners.

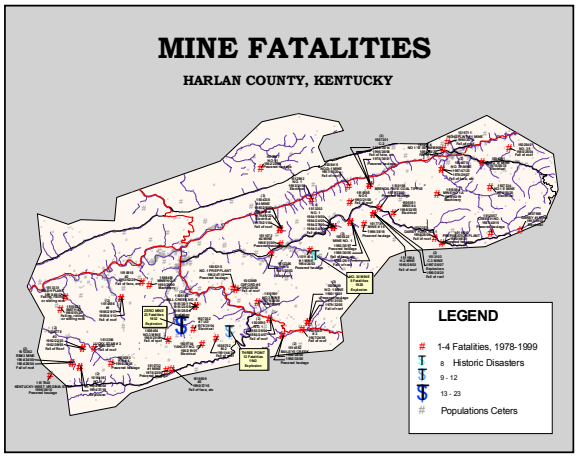
A stress survey specific to underground coal mining has been developed. A pilot study has been designed to assess the use of sequential measures of salivary cortisol as an indicator of stress.

BIBLIOGRAPHY

Newman AB, Shemanski L, Manolio TA, Cushman M, Mittelmark M, Polak JF, et al. [1999]. Ankle-arm index as a predictor of cardiovascular disease and mortality in the cardiovascular health study. Arterioscler Thromb Vasc Biol *19*(3):538-545.

Nordstrom CK, Dwyer KM, Merz CN, Shircore A, Dwyer JH [2001]. Work-related stress and early atherosclerosis. Epidemiology *12*(2):180-185.

Schnall PL, Belkic K, Landsbergis P, Baker D, eds. [2000]. The workplace and cardiovascular disease. Occup Med: State of the Art Rev *15*(1). Philadelphia, PA: Hanley and Belfus.



Using GIS as a surveillance tool.

IMPROVING SURVEILLANCE DATA UTILIZATION THROUGH GEOGRAPHICAL INFORMATION SYSTEMS

RESEARCHER: Nathan T. Lowe

AFFILIATION: Spokane Research Laboratory
National Institute for
Occupational Safety and Health
(509) 354-8000

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

RESEARCH SUMMARY: This research began by producing basic GIS maps that show locations associated with selected mining health and injury information by topic (e.g., accident classification by State or commodity). 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.

KEYWORDS: Mining, surveillance, geographical information systems

Using 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.

Sand and gravel mines are being studied to evaluate the economic and social consequences of an occupational injury.

ECONOMIC AND SOCIAL CONSEQUENCES OF INJURY AT SAND AND GRAVEL OPERATIONS

RESEARCHERS: T.W. Camm, C.M.K. Boldt, and S.R. Ferch

AFFILIATION: Spokane Research Laboratory
National Institute for Occupational Safety and Health
(509) 354-8000

PURPOSE: Determine the economic and social costs of workplace injuries at sand and gravel operations using a case study methodology.

KEYWORDS: Economics, cost of injury, social consequences, systems theory

RESEARCH SUMMARY: The financial and social consequences of workplace injuries and related hazards are poorly understood. Research is needed to increase employer and public recognition and assessment of these costs and their relationship to workplace safety and health investment and performance. This cost information will be useful on many levels: employers, workers' compensation insurers, safety and health consultants.

A workplace injury has direct medical, employment, and earnings consequences for a worker, and these consequences are the focus of a growing body of literature. However, the injury and its attendant medical and labor market consequences are an incomplete description of the effects on the worker and his or her family. In particular, the changed economic circumstances of the family and possible increased care required for the injured worker may affect economic and social outcomes and behaviors for other family members, including children. While fatalities are the most dramatic and tragic, nonfatal injuries may still have devastating impact on families, who often have fewer organized sources of support.

Project researchers will investigate the economic and social consequences of a workplace injury at a small sand and gravel mine through a case study of a recent workplace injury. Investigating the costs of an individual case will enhance understanding of the assumptions used in general cost models. In addition to monetary costs, the project will determine the sociological consequences of the injury in the workplace and in the home. Because of the small number of employees typically found at sand and gravel mine sites, it is anticipated that personal, social, and work bonds and perceptions will be strong and interwoven.

The economic impact will measure both direct costs (i.e., medical expenses, property damage, administration expenses) and indirect costs (i.e., lost earnings, lost fringe benefits, employer costs of retraining). The social consequences model uses three standardized psychological health measures: BDI-II to test for depression, STAXI-2 (state-trait anger expression inventory), and STAIP (state-trait anxiety inventory). A systems theory approach integrating the disciplines of engineering, psychology, economics, and sociology will be used to provide a comprehensive, multifaceted approach to measuring the consequences of occupational injuries.

BIBLIOGRAPHY

Camm TW [2000]. Economics of safety at surface mine spoil piles. Spokane, WA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2001-129, RI 9653.

Camm TW, Ferch S, and Boldt CMK [2000]. The economic and social consequences of injury at sand and gravel operations [Abstract]. In: NOIRS 2000 Abstracts - National Occupational Injury Research Symposium (Pittsburgh, PA, October 17-19, 2000). Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, p. 46.

HEALTH EFFECT STUDIES OF URANIUM MILLERS

RESEARCHER: Lynne Pinkerton, M.D.

AFFILIATION: Division of Surveillance, Hazard Evaluations, and Field Studies
National Institute for Occupational Safety and Health
(513) 841-4344

KEYWORDS: Uranium, milling, cancer, lung disease, renal disease

BIBLIOGRAPHY

Archer VE, Brinton HP, Wagoner JK [1973]. Pulmonary function of uranium miners. J Occup Med *10*:1183-1194.

Waxweiler RJ, Archer VE, Roscoe RJ, Watanabe A, Thum MJ [1983]. Mortality patterns in a retrospective cohort of uranium mill workers. In: Proceedings of the 16th Midyear Topical Meeting of the Health Physics Society (Albuquerque, NM). McLean, VA: Health Physics Society, pp. 428-435.

PURPOSE: To conduct studies of uranium millers to determine if they experience increased mortality or disease as a result of their employment.

RESEARCH SUMMARY: Uranium millers are potentially exposed to uranium ore dust, silica, radon daughters, and acid mists and fumes. Although there are currently no uranium mills operating in the United States, there are public and legislative concerns about potential health effects of uranium milling and whether former millers as well as miners should be covered under the Radiation Exposure Compensation Act, a law that provides compensation to uranium miners. NIOSH (or its predecessor agencies) have previously done two cohort mortality studies on uranium mill workers. Both are limited by small cohort size, absence of exposure data, and inclusion of only white workers. NIOSH's findings that uranium miners have an excess risk of lung cancer and pneumoconioses were considered in drafting the Radiation Exposure Compensation Act. In 1993, the U.S. Army asked NIOSH for help in conducting studies of individuals employed in uranium mills in the Southwestern United States during the period January 1, 1947, to December 31, 1971. This study will provide data of great concern not only to the many surviving uranium millers (especially in light of the known health effects of exposure), but also to workers currently exposed to uranium dust during operations associated with unconventional milling processes.

The goals of this project are to conduct two studies of health effects associated with uranium milling. Researchers proceeded with a cohort update of the previous mortality study by Waxweiler et al. that included seven of these mills and a cross-sectional study of renal and pulmonary effects, which is being done under a cooperative agreement. Analyses of the cross-sectional and cohort mortality studies are now being done.

Cohort mortality studies of uranium mill workers have been limited by insufficient power to detect true differences, as well as a lack of exposure data. These studies will provide important epidemiologic information on the long-term health effects associated with employment in the uranium milling industry. Health effects of concern include lung cancer, lymphatic and hematopoietic malignancies, and lung and kidney diseases. The results of these studies will improve assessment of the association between uranium mill exposures and cancer and other health effects.

A coal prep plant.

NEUROTOXIC CHEMICAL HAZARDS IN COAL PREPARATION PLANTS

RESEARCHER: Gail L. McConnell, V.M.D.

**AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
(412) 386-4207**

PURPOSE: Describe and estimate potential exposures to neurotoxic chemical hazards in coal prep plant workers. Obtain exposure assessments to several known neurotoxic agents used in coal prep plants.

KEYWORDS: Hazard surveillance, neurotoxicity, mining

RESEARCH SUMMARY: NIOSH is proposing to conduct, on a periodic or ongoing basis, a nationally representative survey(s) to evaluate the prevalence and distribution of potentially hazardous working conditions among the U.S. workforce. Additionally, targeted hazard surveys will be conducted in specific industries or occupations as part of this initiative. Targeted hazard surveillance in mines will obtain data descriptive of the health and safety conditions in selected mining commodities, occupations, or workplaces and will determine the extent of workers' exposure to chemical, physical, biological, ergonomic, or safety hazards or select work organization factors. This project is the first scheduled targeted survey in mining. Coal prep plant workers are potentially exposed to several toxic substances, such as acrylamide, solvents, and manganese. The potential neurotoxic effects of polyacrylamide flocculent in coal prep plant workers and neurological disorders due to overexpose to manganese in welders have been reported in the literature.

NIOSH researchers have created a database of neurotoxic chemicals used in coal prep plants based mainly on the National Occupational Health Survey of Mining, which was completed in 1989. A contract has been awarded to update this database in FY02. More information on neurotoxic chemicals now and previously in use in coal prep plants will be obtained by the contractor by conducting focus group discussions in various sectors of the coal prep plant industry (chemical suppliers, mine operators, union and nonunion workers). Information on the use of neurotoxic chemicals not obtained through the focus groups will be obtained through direct inquiries to the three to five major chemical suppliers to the prep plant industry. A comprehensive review will also be done in the English and foreign language literatures. Once the database is complete, work will begin on identifying candidate neurotoxic chemicals for exposure assessments.

BIBLIOGRAPHY

Boiano JM, Hull RD [2001]. Development of a national occupational exposure survey and database associated with NIOSH hazard surveillance initiatives. Appl Occup Env Hyg *16*(2):128-134.

Mulloy K [1996]. Two case reports of neurological diseases in coal mine preparation plant workers. Am J Ind Med *30*:56-61.

NIOSH [1996]. Results from the national occupational health survey of mining (NOHSM). Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 96-136.

Delivering on the Nation's Promise:
Safety and health at work for all people
Through research and prevention

For information about occupational safety and health topics contact NIOSH at:

1-800-35-NIOSH (1-800-356-4674)
Fax: 513-533-8573
E-mail: pubstaft@cdc.gov
www.cdc.gov/niosh

DHHS (NIOSH) Publication No. 2002-110