velop effective solutions that could be implemented promptly. The second goal was to examine the cumulative trauma exposure of roof bolter operators and develop recommendations aimed at reducing the risk of developing injuries. Finally, the team developed materials to educate the mining industry on human factors engineering principles with the intention of improving the design of roof bolting machines.

The following steps were taken to investigate traumatic crushing injuries: interviewed roof bolter operators, analyzed video tapes of roof bolting operations, discussed issues with roof bolter manufacturers, analyzed mine accident data, and reviewed past research on roof bolter safety. The team determined that the goal of any intervention should focus on reducing the probability of a control being accidentally activated and reducing the chances of roof bolter operators placing themselves in hazardous positions around the machine. To achieve that goal, the team developed a list of solutions based on their analysis of the information collected. Some of the recommended solutions include the use of an operator-in-position interlock device, fixed barriers at pinch points, improved control guarding, and reduction in speed of the fast feed. Many of these ideas have already been implemented.

In response to cumulative trauma exposure concerns, members of the project team conducted a study at an underground coal mine to examine roof bolter tasks that performed over time could put the operator at risk. For this study, three primary forms of data were collected and analyzed. Researchers analyzed 43 lost time incident descriptions, conducted a series of interviews with roof bolter operators, and observed operators performing roof bolting tasks. Common roof bolting activities were examined and issues identified as putting operators at risk of injury were discussed. Recommendations were developed which address the three elements which define a system: human, equipment, and environment. The recommendations can be used to increase worker awareness of risk factors, modify job procedures, improve existing equipment, and provide guidelines for future equipment design.

Efforts to educate the mining industry have included the development of seminars on human factors design geared toward design engineers and mine safety personnel, the construction of mockups that demonstrate human factors principles, and the publication of a world-wide-web page devoted to human factors design issues associated with mobile underground mining equipment.

Safety Considerations for Transport of Ore and Waste in Underground Ore Passes**—**Stewart BM, Beus MJ, Iverson SR, Moreland MW

Researchers at the Spokane Research Center of the National Institute for Occupational Safety and Health are investigating methods to improve safety during transport of ore in underground mines and to prevent injuries and fatalities to miners around ore passes. Five fatalities in the last three years were directly related to ore hang-ups resulting in ore pass structural failure and ore chute blowout. Mine Safety and Health Administration (MSHA) accident statistics have identified ore pass hazards. Mine accident data has shown that injuries and fatalities have resulted during ore pass chute and gate operations. Nearly 75% of the accidents related to pulling or freeing ore pass chutes are caused by the use of hand tools and falls of broken rock. Recent ore pass failures have underlined the need for improved designs, standards, structural monitoring methods, and improved hang up prevention/removal techniques. A fault tree analysis identified five leading causes of ore pass failure. Ore pass transport practices and problems at past and present operating mines are discussed.

Design criteria and hang up prevention and remediation strategies include effects of static and dynamic ore and waste rock loads on chutes, walls, gates, and support structures. Particle flow analysis methods were used to simulate the response of various ore pass designs to a wide range of ore loading conditions. A full-scale and 1/3 scale mock-up of ore pass and chute assemblies currently installed were duplicated and tested for load response. Data from the particle flow code, and the mock-ups are compared. Instrumentation and load measurements of an active ore pass will be conducted after the mock-up tests are completed. Development of safer ore pass design and ore handling proceedures are the goals of the project.

Graphical Analysis of Energy Expenditure**—**Belard J-L, Dotson B, Wassell JT, Long D, Wojciechowski W

Waste abatement workers, due to the nature of their job, require a high level of protection and must therefore commonly wear personal protective equipment such as a self-contained breathing apparatus (SCBA) and encapsulating suits. Wearing this type of personal protective equipment while working adds a weight burden, impedes heat exchange and can lead to physiological strain and increased energy expenditure. This strain and increased energy expenditure can in turn lead to exhaustion in a period of time much shorter than would be experienced without this equipment. The goal of this study was to analyze the energy expenditure of hazardous waste abatement workers while performing tasks common to their jobs.

Nine asbestos workers aged 27 to 40 performed six typical hazardous waste abatement tasks in a laboratory setting. Subjects carried an SCBA and wore a Mine Safety Appliances Company (MSA) BlueMaxTM totally encapsulating suit. This level of protection is designated “Level A” and is utilized by workers who require the ultimate possible protection during waste site cleaning operations. Although all subjects were in a safe laboratory environment, they were required to wear this complete protection in order to approximate work site energy expenditures. However, since no activity in a toxic environment was involved, subjects were allowed to keep the garment open and the SCBA disconnected. All tests were conducted in a neutral environment (20°Centigrade, 60% relative humidity). Heart rate, respiratory frequency, and oxygen consumption were measured every 30 seconds during the performance of the various activities.

Six different tasks were selected for simulation through an agreement with hazardous waste abatement union experts. The activities simulated typical tasks performed daily on hazardous waste sites. These typical tasks included: walking from one place to another, carrying equipment, decontamination of soiled surfaces, shoveling toxic dirt into drums, digging to uncover barrels, and crawling in confined spaces. These tasks were simulated with the following activities: walking on a treadmill at 1.5 miles an hour, carrying a 20-pound bucket at the same speed, mopping the floor at 60 strokes per minute, shoveling sand from ground level into a drum, digging at ten shovels per minute, and crawling on the treadmill at 0.3 miles an hour. In all, each tested activity lasted ten minutes, including a five minute warm-up that allowed each subjects' heart rate to reach a plateau. Oxygen uptake data obtained during the last five minutes of each test are used to measure the energy expenditure. The data collected is being analyzed in graphical form.

The risk of impending heat stress increases not only with the ambient temperature, but also with a work load. Results of this study will be useful in determining the workers' average energy expenditure when they perform a given task, and thus to assist with decision-making wether an appropriate micro cooling system is required.

Category: Surveillance

***National Estimates of Occupational Injury from the National Health Interview Survey*—**Geidenberger CA, Jackson LL

The 1988 National Health Interview Survey Occupational Health Supplement is part of a continuing effort by the National Institute for Occupational Safety and Health to improve surveillance of occupational injury and disease. Data from this survey were used to generate national estimates of work-related injury incidence among civilian workers. Eye injuries were a particular focus of the analysis since, in general, such injuries may easily be prevented in the work place at relatively low cost. The overall incidence of occupational injury was 8.6 episodes per 100 workers or 7.2 injured persons per 100 workers. Incidence of injury episode varied by occupation and industry of employment, with injuries occurring most frequently among operator/fabricator/laborer occupations and those employed in the construction industry. Incidence also varied according to body part injured and nature of the injury, with back injury episodes and fractures/dislocations/sprains, respectively, the most common. Risk of injury declined with age for both sexes and was higher for males in every age category. Eye injuries occurred most frequently among those employed in the construction industry and in production/craft/repair occupations. Risk of eye injury was lower than risk of injury to the extremities or back within every occupation and injury category. In addition, those with eye injuries reported fewer days of missed work than did workers with trunk, extremity, or back injuries. Nevertheless, the estimated number of work-related eye injury episodes during the study period (625,745) was substantial, representing 5.9 percent of the estimated total. These results are generally consistent with findings of other injury surveillance systems, and provide further guidance for future intervention efforts.

***Traumatic Occupational Fatalities Due to Falls From Elevations —Cause and Prevention*—**Braddee R, Pratt S

Purpose. To identify and describe trends in traumatic occupational fatalities due to falls from elevations, review recommended prevention strategies, and describe the approach of the National Institute for Occupational Safety and Health (NIOSH) to traumatic occupational fatality investigation and prevention.

Method. This study uses data from the National Traumatic Occupational Fatalities (NTOF), and Fatality Assessment and Control Evaluation (FACE) databases to describe trends and rates of fatalities of workers due to falls from elevations, over a 12-year period. The FACE program, which utilizes the traditional epidemiologic agent-host-environment model to accurately describe the pre-event, event, and post-event phases of fatal occupational injuries, is conducted in the areas of falls from elevations, logging, and machinery-related fatalities. Through surveillance and epidemiologic investigations, potential risk factors are identified and injury prevention strategies developed.

Results. During the period 1980 through 1991, approximately 72,500 U.S. civilian workers died from traumatic injuries suffered in the workplace according to data from NTOF. Over this 12-year period, an estimated 6,721 of these deaths occurred due to falls from elevations. Although the trend of falls from elevations declined from .68 per 100,000 workers in 1980 to .38 in 1991, falls from elevations remain the 4th leading cause of death Nationwide. Between October 1982 and present, the NIOSH FACE program has investigated 79 fatal incidents that involved workers who died as a result of falling from an elevation. Recommended injury-prevention strategies include working in compliance with national safety standards, establishing and implementing written safe work procedures, using proper personal protective equipment and providing appropriate worker training.

Conclusion. Approximately 560 workers die each year from falls from elevations in the course of everyday work situations, and falls remain the 4th leading cause of occupational injury fatalities Nationwide. In order to reduce these numbers, surveillance, dissemination of prevention strategies, and additional research need to be continued. The FACE model has been demonstrated as an effective tool for identifying and describing fatal occupational injuries and developing prevention strategies. The FACE data has been used to produce targeted dissemination of prevention strategies, and to provide input into the promulgation of national safety standards.

***Worker Deaths by Electrocution - A Summary of NIOSH Surveillance and Investigative Findings*—**Casini VJ, Kisner S

Purpose. To identify and describe trends in traumatic occupational fatalities due to contact with electrical energy, review recommended prevention strategies, and describe the approach of the National Institute for Occupational Safety and Health (NIOSH) to traumatic occupational fatality investigation and prevention.

Research Hypothesis. Through surveillance and on-site fatality investigations of occupational electrocutions, risk factors can be identified and intervention strategies developed, disseminated, and implemented to reduce fatal occupational injuries.

Research Data. Data from the National Traumatic Occupational Fatalities (NTOF) surveillance system, which is based on death certificates from all 50 States and the District of Columbia meeting the following criteria: age 16 years and older; external injury cause of death; and the certifier noted that the injury occurred at work was used. Data are also included from the Fatality Assessment and Control evaluation (FACE) program gathered during field investigations using the traditional epidemiologic model.

Method. This study uses data from the NTOF surveillance system and the FACE database to describe trends and rates of fatalities of workers during to electrocution over a 12-year period. Through surveillance and epidemiologic investigations, potential risk fac-