The Story in Brief

Power industry workers are subject to a variety of health and safety risks tied to specific work environments and tasks. The stakes are high. For workers, a single accident or injury can lead to a lifetime of disability, career disruption, and other serious consequences. A single injury can also cost an electric utility a million dollars, and ergonomic-related injuries alone are estimated to cost the electric power industry hundreds of millions of dollars each year. Guided by EPRI risk data and safety handbooks, utilities are now able to target improvements in work practices and equipment that reduce injuries and illness, increase productivity, and control medical expenses.
Job-related illness and accidents can be devastating for workers and have become increasingly expensive for their employers. Although the U.S. Bureau of Labor Statistics reports that the rate of workplace injuries and illnesses for electric utilities is below the national average for private industry employers, the utility operating environment nevertheless involves a number of inherent hazards, ranging from line workers’ potential for electrical contact with live conductors to meter readers’ risks of dog bites. Occupational exposure to a variety of chemical and physical agents raises concerns about worker health and has led to industry regulations addressing polyaromatic hydrocarbons, heavy metals, fly ash, electric and magnetic fields, noise, and other hazards. Increased awareness and prevention efforts have resulted in a steady decline in injury rates at electric utilities, and EPRI is currently working with industry representatives and academic experts through its research programs—in particular the Occupational Health and Safety (OH&S) program, which focuses on ways to further improve the welfare of workers.

**Follow the Stats**

Reducing workplace risks starts with understanding where injury and illness are most likely to occur. For more than 8 years, EPRI has analyzed the statistics needed to make these determinations through its Occupational Health and Safety Database (OHSD) project. By monitoring trends of injury and illness over time and across job characteristics and demographic factors, EPRI’s OHSD has become the industry’s best available source of information concerning risks of workplace injury.

Currently, 16 utilities contribute data to OHSD, including 7 whose records go back to 1995. The full data set now includes more than one million employee-years of follow-up and more than 35,000 observed lost time and recordable injury/illness events among the companies. The study has recorded 41 fatalities, with the largest number (16) observed among line workers. Overall, meter readers have the highest rate of injuries of all types, followed by welders and line workers.

The good news is that the average injury rate across the companies has decreased sharply over the study period—from more than 4.5 injuries per 100 employee-years in 1995 to 1.6 in 2006, the last year for which data are available. Also in 2006, for the first time, no fatalities were reported for the year. The observed decrease is thought to result largely from a growth in utility health and safety programs, improved safety awareness among workers, and increased management attention to occupational safety. Some portion of the decrease may also reflect an increasing use of contractors to perform certain types of work that go beyond routine maintenance—such as new line construction, line renovation, and tree-trimming. Including contractor information is a future goal of this project.

The OHSD differentiates injury rates by job classification, worker age, and cause. Meter readers had the highest rate of injuries—14.07 per 100 employee-years, compared with 12.39 for welders and 12.28 for line workers. By far the largest numbers of injuries for most occupational groups were caused by overexertion and body motions that led to sprains and strains. Meter readers were more likely than other workers to be injured by an animal or insect bite, and line workers were more likely to be injured by falling, being struck, or coming into contact with live electrical conductors. Injury rates tended to decrease with age among trade workers, presumably as a result of cumulative experience and a shift into more-supervisory roles.

“This information is critical for helping individual companies develop targeted interventions to reduce injuries and set benchmarks for specific types of injuries and health problems,” says Gabor Mezei, EPRI senior project manager for OH&S.

“In particular, the analyses provide utilities with the insights they need to adopt successful, innovative approaches to protect the health and safety of their employees.”

**Ergonomics for Productivity and Safety**

Drawing on OHSD analyses, EPRI has focused on helping utilities develop programs that prevent the largest class of injuries—those involving sprains, strains, and related musculoskeletal problems resulting from awkward body positions or movements. Fortunately, the rate at which such injuries occur can be lowered dramatically by improving the ergonomic aspects of common tasks. This includes changing work practices, modifying tools or equipment, and using ergonomic design in equipment and facilities ranging from vehicle fleets to power plants. In many cases, worker productivity also improves substantially.

The showcase achievement of this work has been the publication of a series of EPRI ergonomics handbooks, developed from systematic investigation of a large number of tasks. So far, five handbooks have been published, covering overhead distribution line work, underground applications, direct-buried cable applications, electrical work in fossil-fired power plants, and the design of new generating stations.

The first handbook describes 32 ergonomic interventions to reduce injuries among distribution line workers. Of these interventions, 19 can be implemented for less than $100, and only 7 cost more than $1000. The investigating team concluded that the greatest benefit would be realized by providing line workers with two new tools: a battery-operated press to crimp the sleeve connection between two wires, and a battery-operated cutter capable of cutting wire with a diameter greater than about a quarter of an inch. Line workers have traditionally used a manual crimping press that requires handle force of about 70 pounds. Only about 1% of the general population has the strength to make compression connections with this type of manual press; even for the strong, using a power tool would greatly relieve stress on the shoulders. A survey of medical and workers’ compensation costs shows that preventing just one chronic shoulder
injury, such as tendonitis, could more than pay for the power tools.

Similar recommendations of ergonomic interventions are made in the handbook for underground (manhole, vault, and conduit) applications and in the handbook for direct-buried cable applications. Again, improvements call for battery-powered tools to replace the types of manual press and cable cutter commonly used, along with introduction of a modified lever to remove manhole covers, which can weigh between 250 and 500 pounds. This redesigned manual tool is expected to significantly reduce risk factors for strains and sprains affecting the shoulders and lower back.

Electricians at fossil-fired power plants, who are generally responsible for the installation and repair of electrical equipment throughout the facilities, face a very different set of health and safety risks. For them, recommended ergonomic interventions focus on changing work practices. Handbook recommendations range from the use of knee protection for tasks done while kneeling to the use of modified hand trucks for moving heavy loads up or down stairs. A handbook is under development for power plant operators and general maintenance workers as well.

New power plants provide opportunities to apply ergonomic principles to facility design—to build in systems that can reduce injuries and increase worker productivity. In March, EPRI published a handbook of ergonomic design that includes guidelines for design engineers and a foundation for improving plant specifications. The handbook cites earlier EPRI research indicating that 30–80% of maintenance task time is devoted to setting up a job and that an estimated 30% saving in overall maintenance time could be achieved if access to equipment were improved, making the most important and frequently used components the most accessible. Specific guidelines prioritize design to provide adequate room to negotiate trouble spots and deploy standard maintenance tools.

Investigating Hazardous Substances

Compared with many other workplaces, electric power facilities do not use particularly high levels or large numbers of hazardous substances. Nevertheless, utilities have to minimize worker exposure to a variety of materials, both as a matter of general safety and in response to regulations. EPRI focuses on investigating particular hazardous substances in response to industry needs, and in a long-term project, it is planning to develop an extensive job-exposure matrix to measure worker exposure to both chemical and physical agents.

One current concern is how to comply with new, more-stringent Occupational
Safety and Health Administration (OSHA) regulations regarding exposure to hexavalent chromium—a potentially toxic material produced by certain types of welding commonly used at power plants, substations, and other facilities. Specifically, OSHA now requires employers to evaluate exposures to this material and stipulates that new prevention measures be taken when exposures exceed a level that is one-tenth the previous limit. EPRI is developing a database to represent and evaluate typical welding exposure scenarios. This effort can provide the foundation for determining both the effectiveness of methods to control hexavalent chromium exposure, which OSHA requires to be instituted by 2010, and the need for developing further methods.

OSHA is also considering tighter regulation of worker exposure to crystalline silica (quartz), which is present in coal fly ash. It will be necessary to better measure the concentration of quartz particles in fly ash that are in the respirable size range (less than 10 micrometers) and to distinguish those that are bioavailable—more likely to interact with cells and anatomical structures with which they come into contact. EPRI research used fly ash samples to develop a new test protocol using a computer-controlled scanning electron microscope. This approach was able to distinguish these particles much more precisely than previous methods. Further research is planned to apply this new test to samples of fly ash collected from the air breathed by workers during specific work tasks.

Although the possible health effects of breathing airborne nanoparticles (<100 nanometers in size) remain unknown, rapid advances in the development and manufacture of these ultrafine particles have raised questions about potential risks associated with inhaling them. No studies have been published regarding concentrations of nanoparticles in power plants, so EPRI recently began a project under Technology Innovation funding to assess their presence and characterize their properties. Field measurements will rely on a state-of-the-art nanoparticle aerosol monitor, and samples will be subjected to chemical analysis based on X-ray spectroscopy coupled with transmission electron microscopy. A report on the preliminary findings is expected by the end of 2008.

**EMF and RF Exposure**

For more than 30 years, EPRI has conducted research into the potential health effects of exposure to electric and magnetic fields (EMF), and since 2002, it has led industry efforts to comply with regulations related to worker exposure to radiofrequency (RF) fields. This research is pursued under the EMF Health Assessment and RF Safety program and has led to substantial new insights for applying EMF and RF exposure guidelines. RF exposure among electric utility line workers is a relatively recent development, resulting from the increasing placement of communications antennas on utility infrastructure.

In the 1980s and 1990s, EPRI conducted key epidemiological studies and analyses to investigate whether electrical workers might experience an increased risk of leukemia or brain cancer as a result of workplace exposure to EMF. While these and subsequent major studies in several countries provided somewhat conflicting evidence on this issue, they generally did not establish a strong or consistent connection between EMF exposure and increased risk of either brain cancer or leukemia.

Recent attention has focused on evidence suggesting that electrical workers have a higher risk of amyotrophic lateral sclerosis (ALS), a degenerative nerve disorder commonly known as Lou Gehrig’s disease. No specific link to EMF exposure has been established, and the observed increase in ALS may be associated with some other uncontrolled risk factor in electrical occupations; experience with electrical trauma (such as severe shock) is a leading candidate.

The difficulty in attributing specific health effects to EMF exposure—let alone establishing cause and effect—has renewed emphasis on methods to improve dose and exposure evaluation. High-resolution computer models can show how fields interact
with the human body and can estimate occupational exposures, taking into account that workers are most likely to experience fields that are highly nonuniform.

Whereas uncertainties surround the possible health effects of occupational exposure to low levels of EMF, the current EMF exposure guidelines are intended to prevent well-recognized neural stimulation and other perceived effects, which occur only at very high exposures. Likewise, for RF it is known that absorption of RF energy can heat body tissue and, in some circumstances, cause RF burns—a phenomenon generally associated with high localized RF current density on the skin's surface. As a result, the U.S. Federal Communications Commission has established maximum permissible exposures to RF fields that are related to the specific absorption rate of energy that would result from exposure. EPRI's research work on RF safety supports electric company compliance with these exposure limits and helps establish safe work practices.

A major challenge for compliance is determining what energy would likely be absorbed by a worker under various circumstances. The most intense exposure occurs when workers get close to RF communications antennas, such as those used for cell phone base stations. Their RF fields are typically nonuniform and may in fact be highly focused, complicating efforts to estimate specific absorption rates in personnel at nearby locations. EPRI's RF safety program, using Technology Innovation funding, sponsored the U.K.'s Health Protection Agency (HPA) in-depth dosimetry study, which is based on specific absorption rate modeling that uses HPA's highly detailed, three-dimensional computer model of a man exposed to RF fields. EPRI has also published practical information that electric utilities can use to develop their own RF safety programs and ensure compliance with regulations.

Beginning in 2008, additional research is examining RF burn hazards in the electric power industry. Such burns can occur when workers touch bare communications antennas or metallic utility towers that are located near transmitting antennas. This research will focus on identifying exposure criteria related to RF burns, work practices that may lead to such burns, and methods to mitigate the effects.

“This research is already helping electric utilities develop training programs for their line personnel who work near RF antennas,” says Michael Silva, an engineering expert who manages RF safety research on behalf of EPRI. “Our goal is to work with both electric utilities and companies from other industries, such as wireless carriers, to enhance their compliance efforts and to prevent potentially serious injuries.”

Sharpening the Research Agenda
EPRI has established a new occupational health and safety advisory committee to help guide its research agenda. At its first meeting, in 2007, the committee recommended that all of EPRI's OH&S-related research be linked more closely across the Institute's technical disciplines, bringing a comprehensive approach to defining research priorities. These will include the illnesses and injuries that are the most common in the utility workforce—with an emphasis on risk prevention—and specific areas of concern that require targeted research.

“The committee's guidance has been extremely helpful,” says Robert Kavet, senior program manager for both EMF/RF and OH&S research. “We are already better integrating information from a variety of areas and putting new emphasis on preventive measures, as the committee advised. This effort includes collaborative work between the EMF/RF and OH&S programs to develop a job-exposure matrix that will provide utilities a way to estimate...
Safety Research Across EPRI

EPRI conducts safety-related research in all of its business sectors, providing the electric power industry with a comprehensive, coordinated effort to improve the well-being of workers while also protecting the public at large. The most broadly applicable areas of occupational health and safety (OH&S) research are addressed in the Environment Sector. The other business sectors focus primarily on working with utility members to address OH&S problems that most affect their operations in specific areas. In this way, EPRI provides the industry with an unmatched resource for conducting and sharing a wide-ranging portfolio of OH&S work.

Power Delivery Applications

One safety concern addressed in different ways for more than a decade is the rare but potentially lethal explosion of gases in underground distribution systems. The energy released in such explosions can reach the effect of several sticks of dynamite and can blow off manhole covers, causing collateral damage and injury to the public as well as to maintenance workers. Over the years, EPRI has performed numerous tests involving controlled explosions and has explored several mitigation approaches, including energy-absorbing tethers for manhole covers, pressure-relief devices, and low-cost gas detection systems. Recent attention has focused on using high-speed video to understand and model the dynamics of explosions. A field trial is under way in the Midwest of some 1200 manhole covers equipped with a controlled pressure-relief mechanism.

Other power delivery safety work has focused on line workers who perform live-line work—maintenance on energized circuits. Past research led to development of the EPRI Live Working Guide (1008747) and the on-line EPRI Live Working Resource Center (LWRC), which cover topics ranging from worker training to the proper use of helicopters for live-line work on transmission system conductors. The guide, now under revision, will join EPRI’s “Color Book” series as the Tan Book, while the LWRC will be a living web site, periodically updated with new materials. Current research is focused on identifying new technologies for, and technological gaps related to, live-line work. Topics include minimizing conditions that can lead to arc flashovers, protecting workers from arc-related thermal exposure in transmission and substation environments, improving structure designs to better facilitate live-line maintenance, and improving the protection of workers from induced voltages and currents while they are working on de-energized lines.

Another area of concern for both electrical workers and the public is so-called contact voltage exposure, in which people or animals receive a shock by touching utility infrastructure or other objects, such as water lines and even swimming pool water. EPRI’s research at its test facilities in Knoxville, Tennessee, and Lenox, Massachusetts, has produced a more comprehensive understanding of conditions that can lead to contact voltage and has resulted in development of standard methods for evaluating and mitigating potential sources. This research supports efforts by the Institute of Electrical and Electronics Engineers (IEEE) and other industry groups to set contact voltage standards.

EPRI is also analyzing the electromagnetic compatibility of sensitive electronic devices that must operate in the electromagnetically “noisy” environment of power substations. In the past, standards for ensuring compatibility have sometimes lagged several years behind equipment development. EPRI has drawn on its network of international members and experts to develop best practices for electromagnetic compatibility for the new solid-state power devices and digital electronic control and communications devices now being installed in substations worldwide.

Power Plant Safety

Maintaining safe working conditions at a power plant requires clearly stated goals and procedures, active management participation, and enforced accountability. Although these requirements are met in different ways at different plants, EPRI is well positioned to help identify and com-

the probability of exposure to both chemical and physical agents.”

Such efforts are expected to expand the OH&S program’s value for the industry. “EPRI has played a strategically important role in helping the industry improve worker safety and control health care costs,” says Charles J. Kelly, a member of the advisory committee and director for industry human resource issues at the Edison Electric Institute. “Looking toward the future, EPRI research can help particularly in the areas of reducing injury rates through ergonomic intervention, providing the statistics that utilities need to target their prevention programs, and studying important specific issues, such as radio-frequency burns and worker exposure to fly ash components.”

Kavet points out that a comprehensive approach often yields surprising dividends: “Our initial focus, of course, is on prevention of accidents and health problems, but we are finding that companies with good intervention programs might actually be saving more money through increased productivity than through decreased medical costs. Results like that show that you’re reaching deeper into a company’s culture and influencing it for the better.”

This article was written by John Douglas. Principal background information was provided by Rob Kavet (rkavet@epri.com) and Gabor Mezei (gmmezai@epri.com), with additional information from George Gela (ggela@epri.com), Wayne Crawford (wecrawford@epri.com), and Sean Bushart (sbushart@epri.com).
municate industry best practices, as well as to work with individual utilities on assessing the safety performance of their facilities.

As part of this work, EPRI published the Operations Assessment Guideline (1008250), which provided utilities with criteria for conducting assessment activities at their plants and for comparing the results with industry best practices. The newly updated guideline (1014200) includes application experiences resulting from the use of the initial publication. The Clearance and Tagging Guideline (1014916) was published earlier this year, providing assistance in equipment isolation to protect workers and equipment. In addition, the Maintenance Excellence Matrix (1004705) gives a solid basis for conducting assessments of plant maintenance performance. Future work will focus on guidance for corrective action programs to help members effectively identify causal factors and correct them to prevent recurrence.

Among the most important safety issues at fossil-fired plants are failures of high-energy steam and water piping. EPRI’s collaborative international program to improve boiler life and availability has developed a variety of products, including guidelines and special software, that can help manage piping systems as they age. A related concern is flow-accelerated corrosion, which has been implicated in failures of both piping and turbine blades. Surveys have found that improvements in water cycle chemistry that could help prevent corrosion and other failure mechanisms can be hampered by deficiencies in the technology transfer process. Through its focus on technology transfer, EPRI’s program has become an effective source of guidance, training, and analytical tools for managing flow-accelerated corrosion.

**Radiation Issues**

OH&S research in the nuclear area focuses on minimizing workers’ exposure to ionizing radiation. EPRI’s Radiation Management program includes projects to reduce radiation source term in a plant and to protect workers against radiation from existing sources. A measure of the success of this program is that collective personnel exposure levels are currently at historic lows, and individual exposure levels are well below background for most nuclear power plant workers.

One industry challenge is a lack of international consensus on determining a threshold for releasing workers and materials from radioactively controlled areas, given these reduced exposure levels. Unclear regulatory policy and various monitoring standards mean that clearance for exiting a work area is now effectively determined by the limits of radiation detection equipment, which may vary significantly from plant to plant. In response, EPRI is developing an industry guideline to help standardize best practices for the detection of radioactivity on personnel and materials entering or leaving a nuclear facility.

The Radiation Management program is also facilitating the implementation of advanced software that will help utilities reduce the radiation dose received by workers performing specific tasks, such as reactor head inspection. By using virtual reality software, plant operators can determine the dose that would be received by workers in particular situations and use these results to improve planning and training to minimize exposure during dose-intensive work. The three-dimensional visualization software will enable engineers to reduce operational costs associated with certain complex tasks, such as materials inspections.

Looking ahead, EPRI is leading an industry effort to apply current industry best practices, lessons learned, and technological developments related to radiation management to the next generation of nuclear power plants. Documentation of this work, including specific recommendations, will be published later this year.

**Robert Kavet** is senior program manager of both the Occupational Health and Safety program and the EMF Health Assessment and RF Safety program. Kavet’s first tenure at EPRI was from 1978 to 1984, after which he worked for two years at the Health Effects Institute. Following six years as a consultant on EMF health issues, he rejoined EPRI in 1992. Kavet received both a BS in electrical engineering and an MEE degree from Cornell University; he earned an MS in environmental health sciences and an ScD in respiratory physiology at the Harvard School of Public Health.

**Gabor Mezei** is a senior project manager in the Occupational Health and Safety program. Prior to joining EPRI in 1999, he worked as a physician and epidemiologist at the National Institute of Dermatology in Budapest, Hungary, and at the Toronto Hospital, University of Toronto, Canada. Mezei received a Doctor of Medicine degree from the Semmelweis Medical University in Budapest and a doctorate in epidemiology from the School of Public Health at the University of California, Los Angeles.