Pollution Prevention

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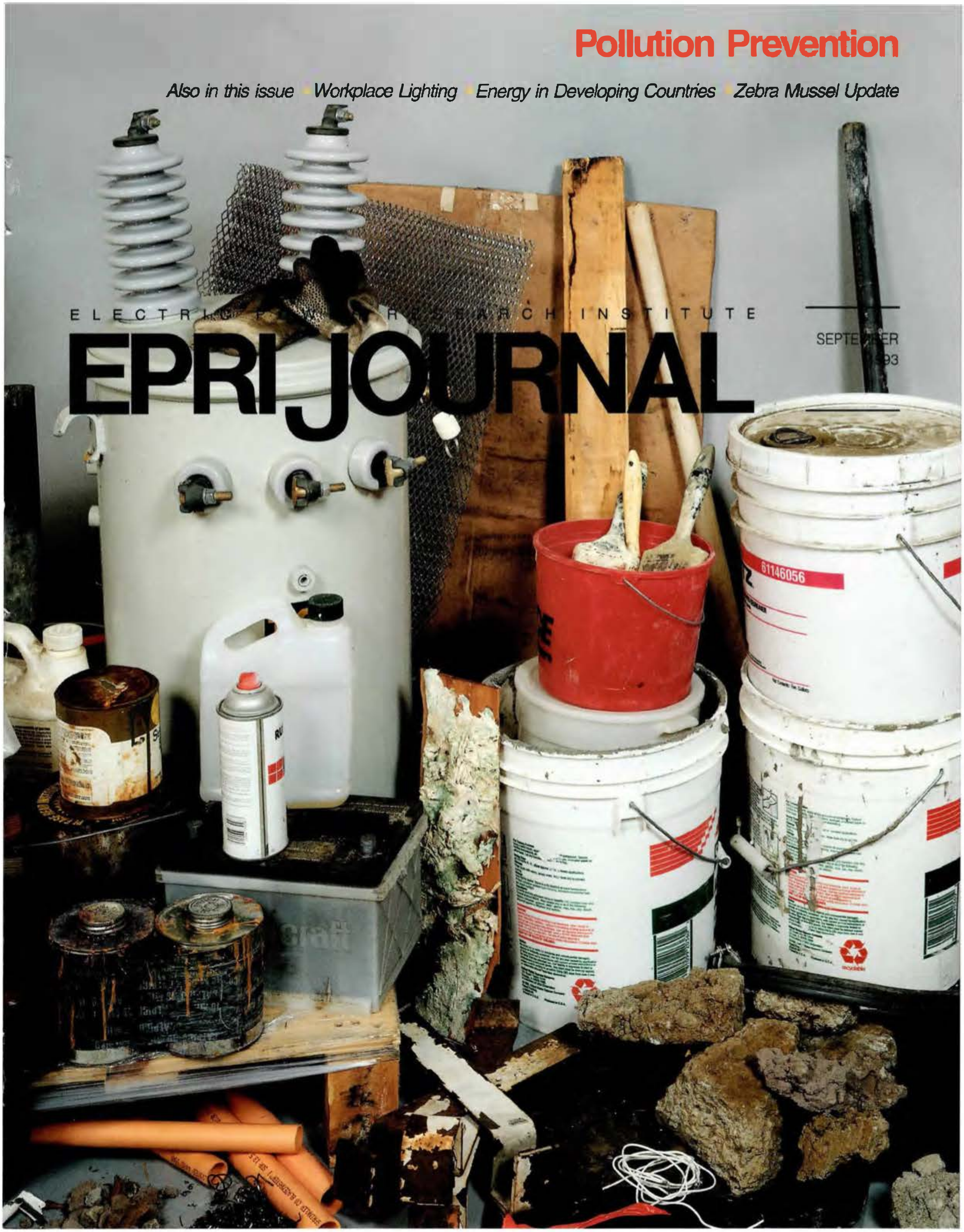

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EPRI JOURNAL Staff and Contributors
David Dietrich, Editor
Taylor Moore, Senior Feature Writer
Leslie Lamarre, Senior Feature Writer
Susan Dolder, Technical Editor
Mary Ann Garneau, Senior Production Editor
Debra Manegold, Typographer
Jean Smith, Staff Assistant

Brent Barker, Manager
Corporate Information

Richard G. Claeys, Vice President
Corporate Communications

Graphics Consultant: Frank A. Rodriquez

Address correspondence to:
Editor
EPRI JOURNAL
Electric Power Research Institute
P.O. Box 10412
Palo Alto, California 94303

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Cover: Utilities are looking at source reduction, recycling, and reuse programs as ways to decrease the volume of a wide variety of wastes produced during routine operations.

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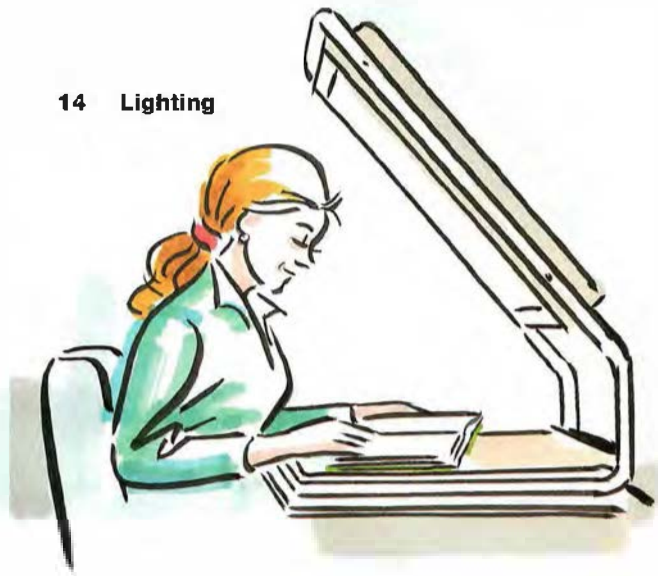

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Emissions Trading Simulators

The pressure is on: your utility must comply with the sulfur dioxide emissions limits set forth by the Clean Air Act Amendments of 1990. But how do you gain experience in the new and unpredictable market for SO_2 emissions allowances (EAs) that was created by the act? EPRI has developed two emissions trading simulators to help resolve this dilemma. These tools are designed to give utilities valuable experience in the SO_2 allowances market without the risks of real-life decisions. From 4 to 20 participants, each operating a simulated utility, can try their hand in the market. The aim is to meet a specified demand for electricity at the lowest possible cost while maintaining compliance—either by purchasing allowances or by controlling SO_2 emissions and possibly selling surplus allowances. With the SO_2 Emissions Trading Simulator (AP-100276), participants juggle operational issues, such as which control technologies to employ, which power plants to operate, and whether to buy or sell bulk power. The SO_2 EA Market Risk Management Simulator (AP-102175) adds a strong element of uncertainty to these issues. Designed to give utilities experience in risk management, this simulator allows participants to travel through a time period of several years as unknown variables such as fuel prices and electricity demand alter the outcomes of their emissions trading decisions.

For more information, contact Gordon Hester, (415) 855-2696. To order, call the EPRI Distribution Center, (510) 934-4212.

PSG's Līn-STAT Thermostat

This product, manufactured by PSG Industries, is the first low-cost electronic thermostat available for electric heating systems. Unlike the low-voltage electronic thermostats on the market, Līn-STAT is a line-voltage technology, which means that it takes its power directly from 110- or 220-volt lines, rather than requiring a transformer to step voltage down. As a result, it is much less expensive and is easier to install. Designed to help customers take full advantage of the benefits of zoned electric heating systems, the thermostat features microchip control for greater comfort and higher efficiency than offered by electromechanical models. It maintains temperature to within 2°F of its setting, achieving this accuracy by allowing the heater to cycle as frequently as necessary. In the event of a power outage, the unit automatically defaults to a setting of 68°F when power is restored. This greatly reduces the danger of pipes freezing. Līn-STAT is available both in a residential model with a decorative cover and in a commercial model with a locking cover so that only authorized personnel can adjust temperature settings.

For more information, contact John Kesselring, (415) 855-2902. To order, call Bill Mayer at PSG Industries, (800) 523-2558.

QuickTANKS 3.0

Leaky underground storage tanks can wind up costing utilities a bundle for soil removal, disposal, and post-cleanup monitoring. But an effective tank management program can help utilities avoid some of this expense. EPRI's QuickTANKS 3.0 software allows utility managers to evaluate tank management alternatives swiftly and effectively. QuickTANKS guides a user through an analysis of existing tank sites. On the basis of information provided by the user, the software recommends a least-cost strategy for managing either individual or multiple underground storage tanks and their related piping—a strategy that meets Environmental Protection Agency regulations.

For more information, contact Bob Goldstein, (415) 855-2593. To order, call the Electric Power Software Center, (214) 655-8883.

Ceramic Filaments for Higher Lamp Efficiency

Scientists at Superkinetic, Inc., of Santa Fe, New Mexico, may have come up with a way to make a better light bulb—using ceramic fibers instead of tungsten alloys as filaments in incandescent lamps. The potential advantages include much higher energy efficiency, longer life, and greater durability. Since lighting accounts for about one-fifth of all electricity use in the United States, such a development could lead to significant energy and cost savings.

The inherent limits of metallic filaments have been recognized for many years: they become unstable as structural imperfections worsen with age and as high operating temperatures cause loss of material from the filament surface and internal embrittlement. Having to maintain a relatively low temperature means that most of the electric energy in conventional incandescent bulbs comes out as infrared, not visible, light.

The goal of current research is to produce ceramic filaments that can operate at temperatures some 500°C higher than is possible for tungsten-based filaments. Because the amount of visible light increases exponentially with increases in temperature, this means that the new lamps should offer significantly more visible light for the same energy input. The spectral quality of this high-temperature lighting is also expected to be superior. And because ceramic filaments can be grown as single crystals with far fewer structural imperfections than their metallic counterparts, they will be less subject to aging and embrittlement problems.

Earlier, Superkinetic received a patent for making light bulbs with single-crystal filaments of silicon carbide. That work provided proof of concept but did not achieve the high operating temperatures desired. Now, with funding from EPRI's Office of Exploratory & Applied Research and its Customer Systems Division, researchers will attempt to create similar filaments from hafnium carbide—a very high temperature refractory material. Eventually, light bulbs made with these new filaments may not only replace conventional incandescent lamps but also compete with halogen lighting, providing greater efficiency at comparable cost, and with fluorescent lighting, providing better spectral quality without the irritating hum.

■ *For more information, contact Karl Johnson, (415) 855-2183.*

Light May Inhibit Corrosion

Researchers at Pennsylvania State University are shining a light on materials used in critical power plant components—not to examine them better, but to protect them from corrosion. Photoinhibition of the corrosion process is a "seductively attractive" possibility for equipment protection because of its elegance and simplicity, says principal researcher Digby Macdonald. "The inside parts of most industrial machines operate in the dark; if we could delay corrosion simply by bringing in light, it would be a relatively easy way to protect them."

In many metals, corrosion begins with the breakdown of the protective oxide film covering their surface. This breakdown, in turn, depends on the accumulation of charged vacancies on the metallic surface just beneath the oxide film. Shining light on the film apparently reduces the buildup of these charged vacancies, thus delaying the onset of corrosion.

Recently completed experiments sponsored by EPRI have confirmed the existence of the phenomenon, Macdonald says, although it is not yet clear whether practical use can be made of the discovery. "I see some room for optimism," he concludes. "It's not as strong an effect as we had hoped for, but we haven't yet optimized the variables."

Specifically, the Penn State team found that light irradiation inhibited corrosion rather weakly in nickel (which has a relatively thin oxide film) but more strongly in copper-nickel alloys similar to those used in power plant condensers and feedwater heaters. The researchers are also investigating an effect in iron, which is the primary constituent of alloys used in turbines. Preventing corrosion in such equipment would presumably involve installing optical fibers to carry light to sensitive areas inside equipment shells.

Macdonald says that the next phase of research would be experiments to further define the practical opportunities and limitations of photoinhibition. Among the many remaining unknowns are the effects of wavelength and intermittent exposure on the inhibition process, and the advantages and drawbacks of various light-delivery techniques.

■ *For more information, contact Barry Syrett, (415) 855-2956.*

Electric Charge Reduces Tillage Energy

The application of a modest electric charge to conventional tillage tools may significantly reduce the amount of energy farmers need to plow their fields. The phenomenon at work is electroosmosis: an electric charge applied to the tilling blade pulls moisture from the soil to the blade surface, providing lubrication that reduces friction as the blade cuts through the earth. Since the amount of tillage energy saved is much greater than the amount of electric energy expended, such a charging system has the potential to significantly reduce the use of fossil fuels in agriculture. Recent laboratory experiments at the University of Arizona have documented energy savings of up to one-third in some types of soil.

Using a laboratory soil bin, the Arizona researchers measured the draft force and the energy required to move a tillage tool through two kinds of soil with varying amounts of moisture. They also examined the effects of various dc voltages and tilling speeds.

In loam soil with a moisture content of 17%—just below the level that causes soil-tool adhesion—draft force was reduced by up to 39% and tillage energy was reduced by up to 32%. The maximum savings were obtained when an electric input of 40 volts was used. Tilling speed had little effect on draft force reduction. In clay-loam soil, electroosmosis was found to be much less effective: the maximum draft force reduction was only 11.6%, and it was obtained with a slower tilling speed and under drier conditions. The reasons for this difference are not yet understood.

The researchers emphasize that full-scale field tests will be required to determine whether electroosmosis will prove effective in actual use. And a better understanding of the wide variation in laboratory results is needed before meaningful economic evaluations can be made and designs optimized.

This research was cosponsored by EPRI's Industrial Program and the National Rural Electric Cooperative Association, and it was managed by the National Food and Energy Council. The study results are presented in EPRI report TR-100446.

■ *For more information, contact Ammi Amarnath, (415) 855-2548.*

Digging Into Po

by Leslie Lamarre

THE STORY IN BRIEF *The concept of reducing waste at the source makes eminent sense: minimizing a problem material at the beginning means generating less waste to cope with later. Source reduction efforts and recycling and reuse activities form the foundation of what is becoming a national pollution prevention movement—a movement that has seen many U.S. industries significantly reduce their waste streams. In the utility industry, rising disposal costs, stringent environmental regulations, and the potential to enhance community relations have all motivated companies to take action. The result has been a wide variety of projects that have targeted such routine wastes as batteries, paint, rags, solvents—even biofouling waste. EPRI is helping utilities set up and evaluate their programs and is developing tools for tracking waste streams and analyzing waste reduction options.*

John Cook didn't climb the corporate ladder and become a vice president at Illinois Power Company just to shovel fertilizer. But that's exactly what he found himself doing one frigid winter day this year. And he's proud of it. "I don't know of any other utility involved in composting," says Cook. "I suspect this idea will probably catch on." It's not that Cook is necessarily fond of fertilizer. Rather, he's keen on waste reduction. And that is the whole point of the compost pile. Comprising some 500,000 pounds of dead fish from the intake system of the power station that Cook manages and a similar quantity of wood chips, the compost is Illinois Power's way of turning a burden into a resource.

Known as the fish and chips project, this unusual endeavor is just one example of the kinds of solutions utilities are finding to reduce a variety of wastes. Faced with mounting disposal costs and increasingly stringent environmental regulations, and seeing the potential to benefit from a positive public image, more and more utilities are tightening the valve on a gamut of waste streams generated in the course of everyday business. They are adopting pollution prevention programs, setting aggressive goals for reducing pollutants, and establishing multidisciplinary teams to

help tackle these goals. Dirty rags, substation batteries, solvents, paints, and oil-contaminated soil are just some of the targets of their efforts.

"Utility activity in waste reduction is steadily increasing," says Mary McLearn, who manages EPRI's pollution prevention efforts. She notes that an EPRI-sponsored conference last December drew more than three times the number of unsolicited papers on waste reduction experiences than were submitted for a 1990 conference on the same topic. "I was surprised at the number of people coming out of the woodwork to present papers. Every time I have a workshop, I meet new people who are working on these issues."

The interest in waste reduction is not confined to the utility industry. It is prevalent throughout the industrial sector, with significant activity under way in companies ranging from chemical manufacturers to automakers. These efforts reflect the ground swell of concern about pollution prevention that has arisen among the American public in recent years. "It has become very clear within the past few years that there is a pollution prevention movement under way," says Thomas McCully, senior policy analyst at the Environmental Protection Agency. Observers like McCully describe this phenomenon as a cultural change or a philosophical shift destined to become as forceful as the total quality management movement that nabbed the attention and energies of corporate America in the 1980s.

"To say it is a cultural shift is no exaggeration," says McLearn. "Pollution prevention involves changing fundamental practices that have been used to run large corporations for decades. That is not an easy thing to do."

First things first

According to environmental experts, pollution prevention—in its purest sense—means preventing pollution before it is generated rather than coping with it after the fact. This approach is commonly referred to as source reduction. But as McLearn notes, the term pollution prevention has come to encompass all kinds

llution Prevention

Broken and defective ceramic insulators get hauled away for use in brick making through a new recycling program at Duke Power. This summer, in the first two months of the program, Duke shipped off 204,000 pounds of insulators. This effort is one of several utility projects across the country geared toward reducing common waste streams.

of activities that reduce environmental impact, such as recycling, reuse, and the creation of useful by-products, as in the fish and chips project. "The first priority of utilities with pollution prevention programs is source reduction," says McLearn, "but that is not always possible."

Indeed, as Michael Lascara, environmental protection manager for Duke Power Company, points out, with current technology it is impossible to operate a coal plant and not generate pollutants. "The laws of thermodynamics govern the amount of sulfur dioxide, carbon dioxide, nitrogen oxides, and fly ash that will be generated," Lascara says. "We can have only a modest impact on these things at the source." As a result, utilities like Duke are turning to the next-best option: putting high-volume by-products like fly ash to constructive use. Currently Duke diverts about 24% of its fly ash for use as a cement substitute in concrete. The utility's corporate strategic plan calls for significantly increasing the percentage of fly ash diverted for reuse over the next five years, aiming for 75% by 1998.

As is the case with combustion by-products, the dead fish that accumulate in the intake system of Illinois Power's Clinton station aren't exactly the type of waste stream you can eliminate at the source. The mass death of gizzard shad in the 15,000-acre Clinton Lake is a natural phenomenon that occurs annually when temperatures drop below freezing. (Enough of the shad survive the winter to produce a new colony when warm weather arrives.) Illinois Power was spending an average of $60,000 a year to have the pungent load hauled away and disposed of. That irked John Funk, facilities supervisor at the Clinton station, who headed up the compost project. "I'm cheap," Funk explains. "Every time we had a vendor come and suck those fish away, all I saw was money going to the landfill."

Determined to find a better solution, Funk picked up the phone and called every place he could imagine that might be interested in a pile of dead fish. He tried cat food makers, dog food makers, and even reclamation companies that put road kill to good use. But there was not a taker among them. "The fish didn't contain enough oil," Funk says. "We were going to have to pay them to take it."

Then, in a conversation with a colleague at the utility's environmental affairs department, Funk learned about a laboratory in Maine that used similar ingredients to make compost. Soon afterwards, the laboratory concocted a recipe calling for equal parts of fish and wood chips. This also provided a productive use for the large quantities of waste wood (railroad ties, broken delivery pallets, and construction remnants) at the Clinton station. Funk purchased a vacuum system to suck up the fish and a grain wagon to haul them away, and he set up a vendor to grind the wood waste into chips. Then he bought a machine to turn over the compost as it lay in rows, decomposing in the outdoor air. Chilly winter temperatures kept potential odor problems in check.

Funk's compost project generated nearly 200 tons of fertilizer in its first winter. Some of this was used to enrich the soil for flower beds and other landscaping at the Clinton station. Ultimately Illinois Power would like to make its compost available to residents and nursery owners in the town of Clinton. Funk estimates the payback period for the equipment he purchased will be about two years.

POLLUTION PREVENTION PRIORITIES **An inverted pyramid is often used to illustrate the order of priority for reducing nonhazardous and hazardous wastes. The first aim is to reduce pollution at the source—that is, to avoid generating it in the first place. When that is not possible, recycling and reuse alternatives are the next priority. Treatment and environmentally safe disposal follow as the last resort.**

At the source

Other waste streams are more amenable to source reduction. Take, for instance, the hazardous solvents utilities use for parts cleaning. Typically these are chlorinated solvents, and in many cases they can be replaced by water- or citrus-based solvents.

The Los Angeles Department of Water & Power is one of several utilities that have successfully employed nonhazardous solvents as substitutes. In fact, in 1992 the utility generated 70% less hazardous solvent waste than it had in 1990. While part of this reduction was accomplished through solvent recycling, the bulk of it resulted from a switch to nonhazardous solvents, primarily citrus-based, says Maureen Palmer, LADWP's supervisor of hazardous waste.

Source reduction is a relatively new emphasis in waste reduction programs. It got a big push from the Pollution Prevention Act of 1990, which many consider the official kickoff of the now-burgeoning pollution prevention movement. The act set a national goal of reducing or eliminating waste at its source. Since its passage, the Environmental Protection Agency has placed a greater emphasis on voluntary programs that encourage source reduction. One of a number of new EPA initiatives is the 33/50 program. Through this voluntary program, formally known as the Industrial Toxics Project, more than 1000 participating companies have agreed to reduce (through methods of their own choice) their release of 17 toxic chemicals. Using 1988 levels as a baseline, the goals are a reduction of 33% by this year and a reduction of at least 50% by the end of 1995. In return, the companies benefit from recognition offered through press releases and special awards issued by the EPA.

John Cook, the manager of Illinois Power's Clinton station and a vice president of the company, is proud to shovel up this sample of compost, otherwise known as fish and chips. Holding the bag is Wayne Bousquet, a coordinator for the compost project, which generated fertilizer from dead fish and waste wood.

Although the utility industry is still in the early stages of experience with source reduction techniques, some utilities with pollution prevention programs are already committing themselves to aggressive goals. Duke Power has established a source reduction goal of 30% for both nonhazardous and hazardous solid waste by 1996. The utility is now in the process of developing a strategy to achieve this goal and has created a new position—waste reduction manager—to oversee the effort. "Our goal is to bring to Duke Power a program that is as successful as 3M's program has been in the manufacturing sector," says the utility's Michael Lascara, referring to 3M's much-publicized Pollution Prevention Pays program. Duke's source reduction effort will build on the achievements already accomplished through the utility's recycling program. In 1992 the power generation portion of Duke (which is separate from the customer service portion) recycled 82% of its hazardous waste and 75% of its nonhazardous waste excluding ash.

Dribs and drabs

The course of EPRI's pollution prevention research reflects the industry's transition toward source reduction. The Institute's work on solvents is one example. Five years ago, EPRI research focused on how to recover and recycle solvents. But gradually since then, researchers have shifted their attention toward studying potential replacements for hazardous solvents in various cleaning processes.

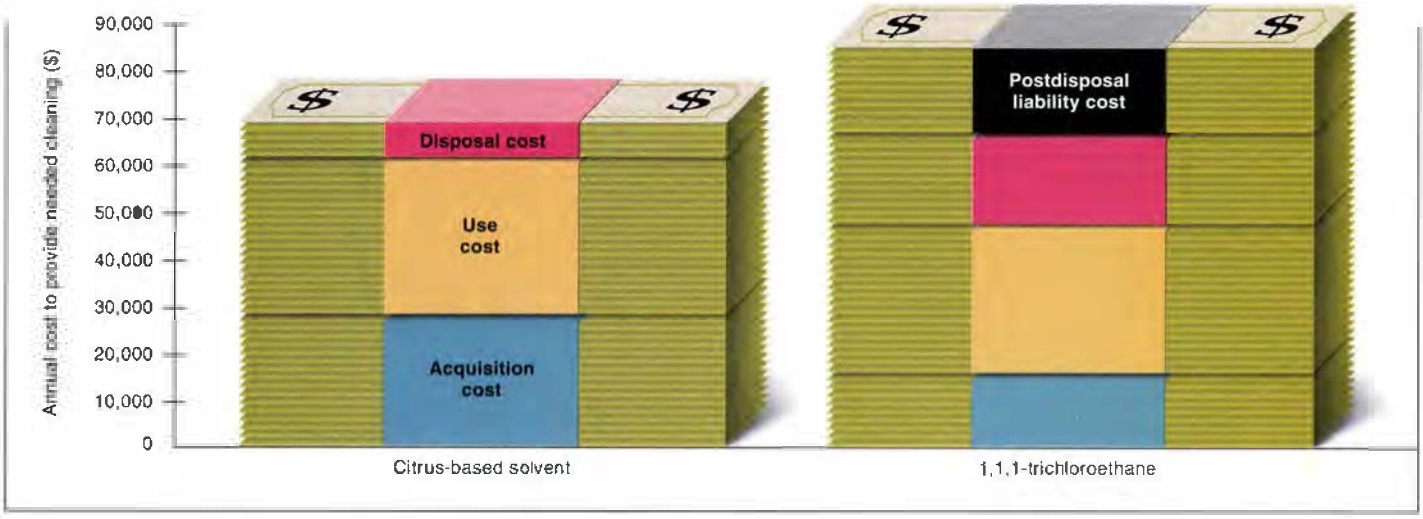
EPRI is now working to specify and test nonhazardous solvents as substitutes for hazardous ones. A project with five member utilities is examining the effectiveness of about 15 nonhazardous solvents. It is expected to be completed by the end of the year.

Solvents are just one of some two dozen types of utility wastes that are the focus of EPRI's pollution prevention project, managed by Mary McLearn. Among the others are biofouling waste (for example, the gizzard shad at Illinois Power), antifreeze, batteries, contaminated soil, paint wastes, mercury, and empty containers—all classified as noncombustion waste. "These are the dribs and drabs from utility operations," says McLearn. "No one was ever quite sure how to deal with them."

Although noncombustion waste streams are relatively small—especially when compared with wastes like fly ash—they can really add up over time. EPRI's pollution prevention project aims to help utilities better manage noncombustion wastes through recycling, reuse, source reduction, and other means. The project's researchers and contractors assist utilities in designing and implementing pollution prevention programs and in documenting their progress. Part of this effort involves the development of tools utilities can use to enhance their pollution prevention programs.

Certainly noncombustion wastes make up just a small part of pollution prevention in the utility industry. Pollution prevention is a much broader issue that encompasses power plant efficiency, renewable energy technologies, and other areas covered by separate EPRI research programs. (Examples of these other research areas are water treatment electrotechnologies, covered in the March 1993 *EPRI Journal*, and recycling, covered in the March 1992 issue.) But the intent of the Institute's pollution prevention project is to use noncombustion wastes as a starting point for the development of tools and methodologies to guide utility efforts. "What we learn from our work with noncombustion wastes can help us with the bigger waste streams," says McLearn. "Ultimately we will be able to apply the knowledge and techniques that we gain

POLLUTION PREVENTION CAN BE COST-EFFECTIVE **Research has shown that utilities should consider costs beyond the purchase price when making decisions on materials. This graph compares a hazardous solvent (1,1,1-trichloroethane) with a citrus-based solvent that carries a higher purchase price. Taking into account related costs—such as those associated with special handling, disposal, and liability—gives a more realistic picture of cost-effectiveness. Utilities have traditionally relied on this type of life-cycle cost analysis for large capital purchases and are beginning to use it for routine materials like solvents.**



to the bigger waste issues, such as air and water."

One soon-to-be-released tool developed in the EPRI project is a software program that will help utilities determine the volume of particular wastes that they generate. Expected to be available sometime this winter, the program—Accounting Software Application for Pollution Prevention—tracks the origin and destination of various waste streams and monitors the costs involved. As McLearn explains, the process is similar to the financial accounting process of small businesses, only the software user is counting not only dollars but also pounds of waste.

Lascara of Duke Power believes this kind of tool will soon be in great demand. He notes that legislation like the Community Right-to-Know Act of 1986, which requires manufacturing facilities with more than 10 employees to report annually on their release of nearly 330 chemicals, is forcing companies to more closely monitor the wastes they generate. Although the utility industry is currently exempt from the requirements of the 1986 act, Lascara says that Duke is already preparing for the day the industry faces similar requirements. "We believe it's just a matter of time," he says.

Many drivers

Incentive to beef up pollution prevention efforts is coming from many directions. Mounting landfill fees alone provide motivation to reduce both nonhazardous and hazardous wastes. And the cost factor has been compounded by a spate of federal environmental laws.

For instance, regulations resulting from the Resource Conservation and Recovery Act (Subtitle C) mandate special procedures for wastes defined as hazardous. These procedures include new storage, transportation, predisposal treatment, and paperwork requirements. State regulations are taking a similar tack. About 20 states have enacted laws that either require or encourage industries to identify and invest in pollution prevention measures. And several other states are considering voluntary programs to promote pollution prevention.

Industries across the country are hoping to stay one step ahead of environmental regulations by establishing standards to guide pollution prevention activities. Utilities and chemical manufacturers are among the various industries providing their input through this effort, organized by the American Society for Testing and Materials (ASTM).

An open society of professionals from educational institutions, government agencies, research laboratories, and businesses, the ASTM has developed international test standards for materials, products, systems, and services for the past 95 years. ASTM standards are often adopted by regulatory agencies. For instance, the society's standards on leak detection and cleanup for underground storage tanks were adopted by the EPA.

In September 1991 the ASTM formed a subcommittee on pollution prevention, reuse, recycling, and waste reduction. Michael Miller of EPRI, who oversees the Institute's Waste & Water Management Program and helped establish the subcommittee, explains that utilities were interested in creating voluntary standards for pollution prevention as an alternative to having standards imposed by the federal government. "The feeling is that utilities know better how to make the standards applicable to the industry," Miller says. "They understand the level of detail that would be appropriate to encourage pollution prevention."

The ASTM's efforts have already resulted in a draft guide on pollution prevention. The document, which is expected to be published by the end of the year, will define the key elements of successful pollution prevention programs and will describe how to implement effective education and training and how to track progress. Other ASTM efforts focus on the development of specific standards to support pollution prevention measures. For instance, the society is developing a standard test for coal fly ash that will indicate whether a given batch of ash can be used for structural fill and other construction purposes without treatment.

Regulations are not the only factor motivating utilities to implement pollution prevention measures. Perhaps even more important, utilities are finding that in many cases pollution prevention makes good economic sense. "Money is the real driver for a lot of utilities," says McLearn. "And more and more utilities are becoming aware of the economic advantages pollution prevention can offer."

Jay Eingold, waste minimization coordinator for Florida Power Corporation, says that a three-month pilot rag-recycling program saved the annual equivalent of $12,300 and resulted in the recycling of 55% of used shop towels, a waste stream that was previously discarded. "In the scheme of a major utility's budget, $12,000 isn't going to make or break a year," Eingold goes on. "But if this program were implemented companywide, the savings could cover the salaries of numerous employees."

The life-cycle factor

As McLearn explains, the savings advantages aren't always obvious until the true cost of a material is known. A variety of costs—for example, costs associated with storage and transportation, with special handling procedures or disposal processes, and even with future liability—can accumulate over the lifetime of the material, often adding significantly to the initial purchase cost.

This is what Northern States Power found in a cost comparison of hazardous and nonhazardous solvents for parts cleaning. The NSP study compared the cost of the continued use of hazardous solvents with the cost of an automatic parts washer utilizing an aqueous solution. The parts washer option carried a higher purchase price. However, as the study showed, that option generated roughly one-half the amount of hazardous waste and offered savings of up to $40,000 a year in labor costs at the plants that used the washers. Additional benefits included reduced employee exposure to solvents and reduced hazardous waste fees, taxes, and disposal costs. As a result of this study, NSP has purchased parts washers for seven of its facilities.

Accounting for related costs to arrive at the true cost of a product—a procedure known as life-cycle cost analysis—is nothing new in the utility industry. Utilities have relied on life-cycle cost analysis to make decisions on big machinery purchases for decades. Typically, however, they have not performed such analyses for the purchase of materials like paint, rags, wood poles, and solvents. One important element of EPRI's current pollution prevention efforts is the development of a software program that will perform life-cycle cost analyses for these kinds of materials.

"This tool will provide a better understanding of the real tradeoffs between cost and environmental impact," says McLearn. "Once utilities perform life-cycle cost analyses, they will realize that in a lot of cases the product with the lowest purchase price can be far more expensive over its lifetime than they ever imagined." Of course, the dollars don't always add up in favor of the option with the least environmental impact. When they don't, recy-

This mountain of mulch at Duke Power is a concoction of broken delivery pallets, construction remnants, tree trimmings, and other waste wood—all ground up together. The mulch is used for landscaping at the company. Duke also allows employees to take the material home for use in their own yards.

In a pilot program at the Los Angeles Department of Water & Power, recyclable shop towels were substituted for throwaway paper towels to reduce the generation of oil-contaminated waste. Other utilities, including Florida Power Corporation, have implemented similar programs.

cling and reuse options may make better sense.

McLearn notes that many costs incurred over the lifetime of a product are uncertain to some degree. Price increases, workplace accidents leading to medical liabilities, chemical spills with high cleanup costs, and disposal site contamination that can result in large liabilities several years after disposal are all factors that can contribute to cost uncertainty. The life-cycle cost analysis program is designed to recognize and account for such uncertainties. If a range of estimates for each uncertain cost is specified, the analysis can capture the range of possible cost outcomes. As well as helping utilities select least-cost options for reducing waste, this program will allow them to quantify trade-offs between cost and waste minimization. A beta version of the software is expected to be released next year.

Knowing the true cost of materials does not necessarily guarantee the purchase of the most cost-effective products. Many utilities confront organizational barriers. One common problem is that different departments are responsible for purchasing and for disposal costs. As a result, the purchasing department may not understand the justification in opting for a product with a higher purchase price but a lower life-cycle cost. "This can be a real hurdle to pollution prevention efforts," says Jay Eingold of Florida Power Corporation, where responsibility for disposal is centralized in one department. One incentive under consideration at Florida Power is to bill each department for its own disposal expenses. "That way, each group would actually see and feel the cost impact," Eingold says.

People and quality

Another hurdle in the path of pollution prevention is the potential for resistance from people in the field. As EPRI's Michael Miller explains, a product substitution may not sound like an ordeal on paper, but in practice it could require significant adjustments from the people who work with the material. For example, workers may find that refillable containers with hand-operated spray triggers are not a good substitute for aerosol spray cans because use of the trigger makes their fingers sore.

"It's important these people be asked for their input," McLearn says. "Product substitutions may require major adjustments in day-to-day activities. This is what we mean when we say that pollution prevention involves a cultural change."

In many cases, field workers have provided useful feedback, pointing out some serious drawbacks that hadn't occurred to the organizers of pollution prevention efforts. For instance, in one EPRI survey utility workers reported that while the citrus-based solvents were technically effective as substitutes for hazardous solvents, they raised some health and safety concerns. Workers who used the new solvents to clean parts on utility lines reported that they attracted swarms of bees. And workers who used them in poorly ventilated areas reported that their strong odor caused headaches.

"Traditionally, no one has encouraged the input of people in the field," says McLearn. "And yet this is where we've gotten some of our best ideas—from the people in the overalls, the ones who are working with the stuff." In some instances, as with Illinois Power's fish and chips project, a great idea has come directly from a field worker. This was also the case at Florida Power Corporation, where the initiative for the utility's now-thriving recycling program came from an analyst in the purchasing department, Joe Alonge.

Alonge proposed the idea of a recycling

Pacific Gas and Electric Company recycles 85% of the metal from its fluorescent lamp ballasts. Drums filled with the ballasts are delivered to a PG&E contractor. Later, external and internal wires from the ballasts, as well as the ballasts' metal casings, are recovered for recycling.

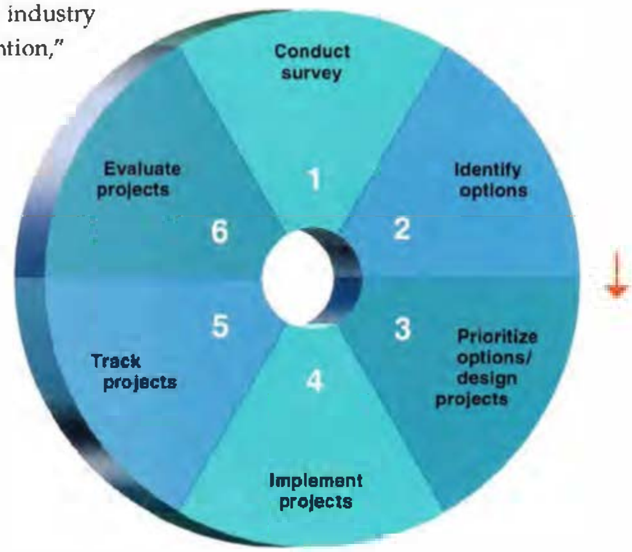
program in a letter to his senior vice president in 1989. Now, as resource recycling coordinator for the utility, Alonge oversees the entire program. In 1992, he reports, Florida Power recycled 1.1 million pounds of untreated wood, plastic piping, office paper, cardboard, porcelain insulators, and laser cartridges. This year the utility's senior executives established a corporate goal of improving on these achievements by 25%.

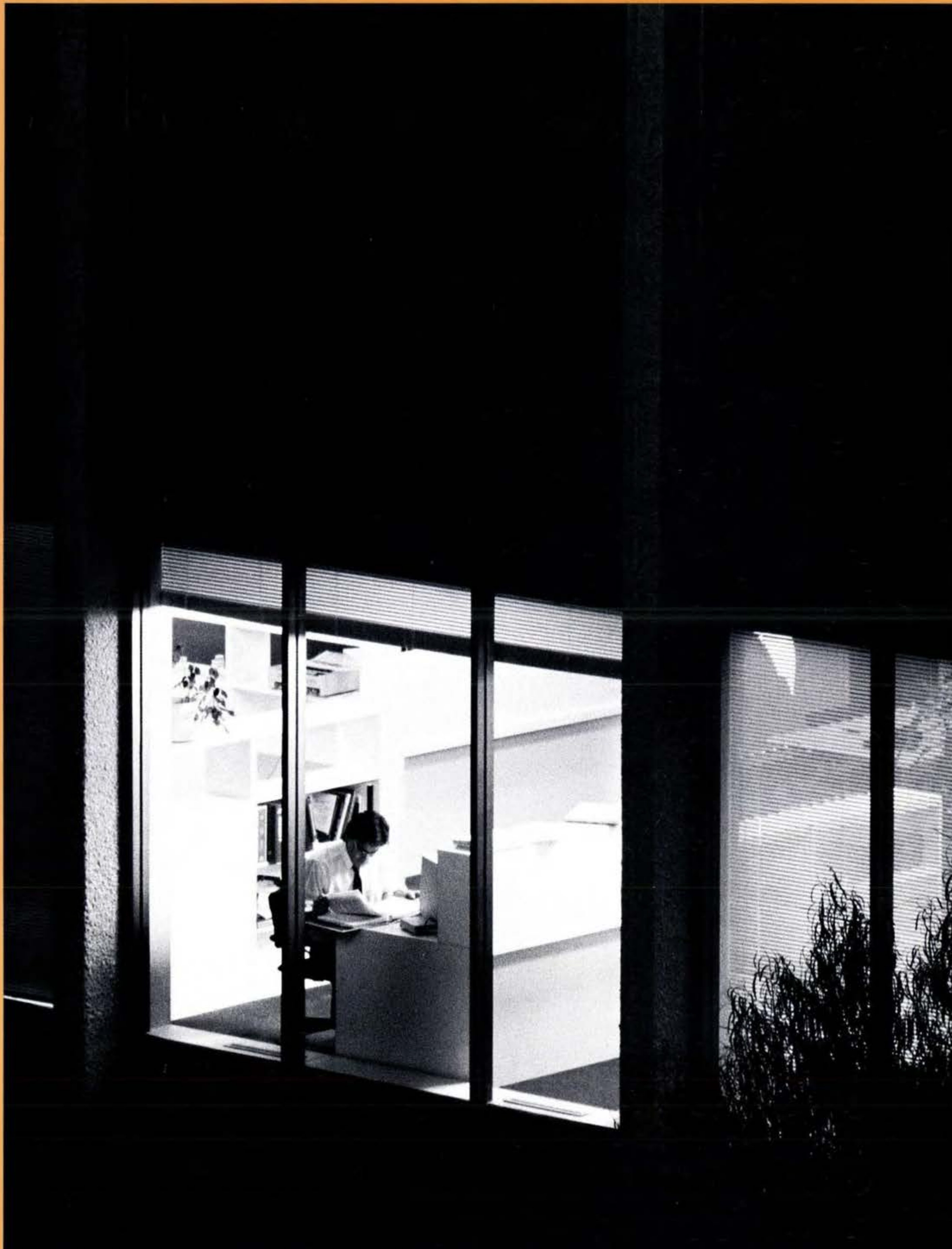
The involvement of field personnel is one of many elements that pollution prevention programs and total quality management programs have in common. An approach to quality improvement pioneered by W. Edwards Deming, total quality management has swept the nation's industrial sector over the past decade and is now used in a wide variety of manufacturing and service companies, including utilities. A crucial facet of total quality management is continuous improvement—another element it shares with pollution prevention programs. "Utilities need to continually reevaluate their programs after they are fully implemented, rather than just wiping their hands and saying they're finished," says Miller. "They may have instituted a recycling program, and then a new technology or process comes along and opens the option of source reduction instead."

Some say that pollution prevention will follow the path of total quality management to find its place as a mainstay of U.S. industries. Michael Lascara of Duke Power is among them. "I believe industry is serious about pollution prevention," he says, noting that Duke has specifically taken the principles of its total quality management programs and applied them directly to its environmental efforts. "Not only is it the right environmental thing to do, but it's good for business. In the long run, it costs less to prevent problems than it does to correct them, and that goes for pollution prevention as well as for quality. That's why end-of-the-pipe solutions by themselves are not good enough. We've got to strive to prevent pollution at the source." ■

Background information for this article was provided by Mary McLearn and Michael Miller, Environment Division.

A CONTINUOUS PROCESS **Like the total quality management philosophy now guiding many U.S. companies, the pollution prevention process emphasizes continuous improvement. The foundation for this process is a corporate commitment to pollution prevention. Once commitment is secured, EPRI researchers suggest, utilities should follow the six-step process shown here. As technical and regulatory developments shift the options for pollution prevention over time, utilities should revisit the process.**





Human Performance in the Spotlight

by Taylor Moore

THE STORY IN BRIEF New insights about how light exposure affects human physiology are leading some experts to an interesting conclusion: indoor lighting that is much brighter than typically found in working environments may have a beneficial, stimulative effect on worker performance. While the possibilities are intriguing, boosting lighting levels runs counter to the energy conservation practices of the past two decades. Continuing exploratory research in neurobiology is studying the effects not only of lighting intensity but of such other factors as wavelength and time and duration of exposure. Finding the best combination of these factors could maximize the potential performance benefits while avoiding drawbacks like increased energy consumption and visual glare. Research results could ultimately lead to improved lighting designs and illumination guidelines, particularly for helping shift workers resynchronize individual circadian rhythms.

Over the last decade, scientists have learned with increasing certainty that the daily cycle of sunlight and darkness, quite apart from affecting our vision, exerts a powerful biological influence on humans. For nearly all mammals, the light-dark cycle regulates circadian (daily) and seasonal body rhythms, hormones, reproduction, and metabolic processes. In people, a distinct form of winter depression known as seasonal affective disorder is believed to stem from the shorter days and reduced light stimulus of the fall and winter months.

In apparent confirmation of such biological effects, doctors and other specialists have been using bright-light therapy to successfully treat most of the 1 in 20 people who suffer serious symptoms of winter depression—symptoms that include lethargy, weight gain, withdrawal, increased need for sleep, and difficulty concentrating. For those patients and the numerous other people who report mild symptoms, such phototherapy is now available from many clinics around the country. Meanwhile, other pioneering studies have begun exploring the use of light therapy to reset the body's internal clock for two special groups of people in whom it gets out of phase: air travelers suffering from jet lag and shift workers. The treatments and research have spawned a small industry producing such innovative light devices as bright fluorescent panels, fluorescent workstations, and lamp visors for therapeutic use and for fending off jet lag.

As insights into the nonvisual biological effects of light have accumulated, a prominent medical researcher who has been involved in many of the key studies says he is convinced that this work could spark the next revolution in architectural interior lighting design. And it has special relevance for the nation's 20 million workers whose jobs require them to work evenings or nights on a fixed or rotating basis, including many workers in the electric utility industry. Numerous surveys report impaired performance or productivity as a result of reduced alertness and other symptoms among various types of shift workers.

"Light is an energy with profound biological and health consequences for human beings that extend far beyond the question of adequate illumination for visual acuity—this is now well established," says George Brainard, an associate professor of neurology and pharmacology at Thomas Jefferson University's Jefferson Medical College in Philadelphia. "Data from laboratory studies in recent years very clearly indicate that properly controlled light can influence human physiology, mood, and behavior. Soon it should be possible to begin incorporating these insights into practical lighting designs that can optimize biological stimulation as well as provide correct visual stimulation and comfort—but that are also as energy-efficient as possible," Brainard adds.

That kicker could prove to be the real challenge in getting new insights about light and human performance factored into lighting designs and illumination standards. Such standards are entering a new phase of downward ratcheting as part of the latest and broadest drive to increase the efficiency of energy use throughout the economy. Accounting for about one-fifth of total electricity consumption, lighting is a major focus of retrofit incentive programs and new designs to reduce energy use, often in part by reducing indoor illumination levels.

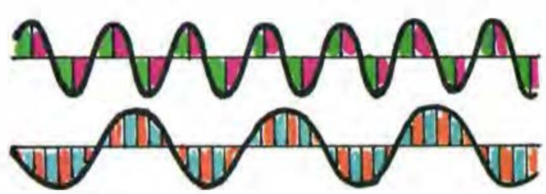
"The drive for energy efficiency over the last decade has led to a continual tightening of standards for interior lighting levels in the workplace, while over the same time period new discoveries in neuroscience have shown that bright light—indeed, three to five times brighter than is specified in new energy conservation standards—may be essential for effective functioning of human daily biological rhythms," says Thomas R. Schneider, an executive scientist in EPRI's Office of Exploratory & Applied Research and the former president of the Lighting Research Institute.

IRRADIANCE

THE FOUR FACTORS OF LIGHT'S BIOLOGICAL EFFECTS
The impact of artificial light on human biological rhythms is more than a simple matter of the intensity of illumination. Experiments with humans and other species reveal that the ability of light to alter circadian rhythms and suppress melatonin synthesis is the product of four key parameters: irradiance (intensity), wavelength, time of exposure, and duration of exposure. Scientists at several laboratories and universities are pursuing studies to identify the optimal combination of parameters for achieving a biological stimulus without the use of extremely bright light. Animal experiments indicate, for example, that light of predominantly blue-green wavelengths may suppress melatonin synthesis at relatively low irradiance.

TIME

DURATION



WAVELENGTH

Schneider says that the recent research on the biological effects of light, some of it supported by EPRI, suggests that the currently recommended lighting levels may be too low for many types of shift work that require sustained performance and mental acuity. This may have particular near-term implications for utilities in the case of power plant operators and system dispatchers at energy control centers.

And the new insights on the use of light as a biological stimulus could have much broader economic and social value if, as Brainard and other experts believe, they can be applied to benefit most shift workers and even some day workers. A study by the congressional Office of Technology Assessment (OTA) two years ago concluded that poor adaptation to 24-hour operations among variable-shift workers has a significant negative impact on overall economic productivity in terms of increased costs for health care, accidents, and training. Experts at a committee hearing on the study estimated the cost to the nation's gross domestic output at about $70 billion a year.

The melatonin connection

The first experiments to demonstrate a nonvisual human response to light were conducted in the 1980s. Led by Alfred Lewy, then with the National Institutes of Mental Health (NIMH), those studies revealed that bright light shone into a person's eyes at night can cause a marked decline in the body's usually high nighttime synthesis of melatonin.

One of the most potent yet esoteric of the endocrine hormones—sometimes jokingly called the vampire hormone because it appears almost entirely at night—melatonin acts as the body's neuroendocrine transducer, as Brainard explains. It is produced by the pineal gland (a part of the brain that is not directly associated with the visual system) in response to nonvisual, darkness-triggered nerve signals from a part of the hypothalamus called the superchiasmatic nucleus—believed to be the true center of the body's biological sense of time of day and season. Melatonin transmits those signals in chemical form throughout the body via the bloodstream. But that is only one of many roles ascribed to melatonin. Some researchers have evidence that it is involved in controlling the immune system and can inhibit the growth of certain tumors.

Not only does exposure to bright light at night strongly suppress melatonin, but the daily light-dark cycle is known to entrain, or synchronize, the body's synthesis of melatonin to a 24-hour day. The melatonin signal, in turn, entrains other hormone cycles, some of which have seasonal aspects tied to the changing length of the days. In experiments with small animals, the levels of a number of these other hormones can also be modulated by the manipulation of light exposure.

The earliest experiments in humans failed to find a regulating effect of light on circadian and seasonal rhythms, as had long been observed in nocturnal animals. That turned out to be because the light intensities sufficient to trigger melatonin suppression in the animals were much lower than needed for a similar response in humans. Lewy and his colleagues saw a 60–80% decrease in circulating melatonin within 1 hour of exposing the eyes of normal volunteers to 2500 lux of white light for 1 hour. Typical interior lighting intensities of 500 lux, however, did not produce a suppression effect.

Those experiments were soon followed, in 1981, by the first trial of light therapy for winter depression, which had been proposed to the NIMH researchers by Herb Kern, a Bell Laboratories engineer, for treating his own symptoms. Six hours of daily exposure to 2000 lux of white fluorescent light reversed Kern's depression within a few days.

In the case of winter depression, researchers hypothesize that the absence or weakness of day-night cues encoded as neuroendocrine signals allows the body's hormonal and biological rhythms to get out of sync. In the case of long-distance jet travelers, who hop time zones, and shift workers, who force themselves to be awake when their internal clock says they should be asleep, their bodies get conflicting day-night cues, causing significant phase shifts in body rhythms that lead to unpleasant symptoms.

For all these groups, it appears that in most cases controlled light therapy can readily reset the body's clock to a proper 24-hour day within a short time. But the light intensities involved in most phototherapies today and in the early experiments—2500 lux (about 250 footcandles)—are five or more times brighter than the approximately 300–500 lux (30–50 footcandles) typical of indoor work environments. Brainard notes that while 2500 lux may seem bright indoors, "that is still less than the twilight of a normal dawn before the sun comes up. In contrast to typical indoor light, full dawn light is three times more than is needed to get a stimulus effect."

In more recent studies, Brainard, Lewy, and others have tried to identify the particular wavelengths that are the most biologically effective. Preliminary evidence indicates that wavelengths in the blue-green portion of the spectrum are the strongest for melatonin regulation. Although Brainard and researchers at the NIMH have begun testing for the most effective wavelengths for depression therapy, the optimal balance of wavelengths is not yet known.

In addition to the standard 2-by-4-foot box of fluorescent tubes that is now widely used for therapy, Brainard and others in the field have developed and experimented with their own designs for light-therapy appliances. These devices include battery-powered portable light goggles and visors for workers or airline passengers needing moderate amounts of illumination. They also include a stationary overhead workstation panel that can provide 10,000 lux and reduce the typical light-therapy treatment to half an hour. The latest in therapeutic light devices—a dawn simulator—is an incandescent light in the bedroom that brightens slowly to mimic the rising sun and awaken a sleeping patient.

The stimulative power of light

Although the physiological consequences of suppressed melatonin synthesis are not fully understood, the hormone's central role as a neuroendocrine transducer and timekeeper for other body rhythms means that a disruption of its normal cycle can have numerous implications for a person's biological and psychological well-being. On the positive side, bright-light exposure can reverse debilitating phase shifts in the biological clock. And recent experiments by Brainard and others indicate that such exposure may increase the ability for sustained performance.

In studies funded by the U.S. Air Force as part of a broader research program on factors that may extend critical performance under active battle conditions, Brainard and others found that volunteers taking cognitive tests at computer terminals could in many cases work for longer periods without tiring when overhead lighting of 3000 lux was provided. At least five studies have used bright-light stimuli for periods of sustained performance ranging from 16 to 48 hours in length. Researchers looked for changes in melatonin synthesis, body temperature, and performance. Although temperature shifts did not always result from the light exposure, performance improvements were seen more than half the time and melatonin levels were consistently suppressed.

Two recent studies by other researchers have focused on the use of bright light for daily shift work, as opposed to long periods of sustained performance. In both of these studies, night-shift workers exhibited improved performance with brighter-than-normal light.

"Beyond the military and its interest in personnel who operate multimillion-dollar weapons systems, there are many demands for sustained performance by workers in everyday life and in various emergencies and disaster recovery," Brainard notes. "So there is great interest in—and, in fact, a great need to examine—the use of bright light in enhancing human performance." He and several colleagues have recently taken particular interest in the application of light stimuli for shift workers who must perform critical functions consistently well over a sustained period. Moreover, adds Brainard, "we are increasingly interested in getting beyond the use of portable or semiportable bright-light devices and investigating whether we can achieve the therapeutic and stim-

ILLUMINATING LIGHT'S IMPACT ON HUMAN PERFORMANCE **Laboratory investigations of physiological responses to bright-light exposure may help identify methods of improving human performance, particularly in extended shift work. An experimental facility for studying how architectural lighting affects humans has been constructed at Jefferson Medical College in Philadelphia, where Dr. George Brainard and his colleagues are conducting computerized behavioral tests on volunteers under various lighting conditions. The studies, sponsored in part by EPRI, are examining the effects of light on hormone production and other physiological parameters and on cognitive performance. The researchers are also measuring the energy consumption of the lighting schemes. The ultimate aim is to identify energy-efficient lighting systems and architectural designs that can enhance human health and performance.**

ulative effects from lighting designed for general use."

Brainard and his colleagues have been pursuing these issues in a recent series of experiments involving volunteers who work for various lengths of time in a specially developed laboratory with a built-in luminous ceiling that can deliver a range of illuminance from 0 to 4500 lux. In this zonally controlled simulated working environment, healthy subjects work in partitioned booths on tasks at computer terminals while their behavioral performance and biological responses are monitored. Parameters of interest can be tested under a variety of realistic and simulated conditions. This research is supported by several organizations, including EPRI, the National Aeronautics and Space Administration, the Lighting Research Institute, and various lighting companies.

One question the researchers hope to answer is whether there are intermediate levels of intensity of biologically effective light between the 2500 lux known to stimulate the circadian system and the 300–500 lux believed to have no biological effect. It's known from previous studies that the suppression of melatonin is the product of four variables of light exposure: the irradiance, or intensity; the wavelength; the duration of exposure; and the time of day of exposure. Further studies are expected to identify the optimal combination of exposure factors for providing a biological stimulus at a minimum level of light intensity.

"With built-in architectural light, we know that 3000 lux can be an effective biological stimulus during the night, but it is possible that 2000 or 1000 lux may be just as effective. Working with built-in task lighting that is closer overhead and fills the field of view, it may be possible to induce biological effects with illuminances well below 1000 lux," says Brainard.

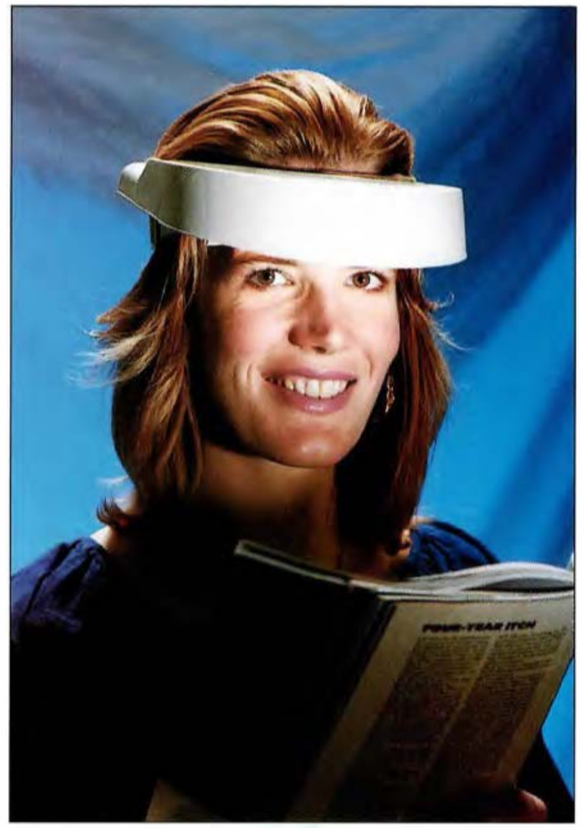
The researchers are also pursuing studies to clarify the exact mechanisms in the eye that drive the nonvisual biological effects. "If we can understand more about whether rods or cones are involved, for example, it will help define the most effective lighting configuration. Our ultimate aim is to determine lighting designs that

TREATMENT SPAWNS PERSONAL LIGHT-THERAPY DEVICES

Over the past decade, the success of bright-light therapy as a treatment for a seasonal form of depression has spawned a variety of therapeutic light devices. Developed at Jefferson Medical College, the National Institutes of Mental Health, and elsewhere, the devices range from the commonly used fluorescent tube box to overhead panels, visors, and other headgear that can deliver light at various levels of intensity.

2500 lux

400–3200 lux



0–2500 lux

4000 lux

10,000 lux

are optimal for visual stimulation, visual comfort, and biological regulation —in addition to being energy-efficient," Brainard adds.

Shedding light on control room lighting

What constitutes normal or adequate lighting depends, of course, on a lot of factors, not the least of which is the nature of the work or activity that is to be done in an illuminated area. Furthermore, various functional, design, and security requirements can impose limitations on interior lighting design, sometimes making it difficult to balance everything in an ideal configuration.

New research on the biological effects of light notwithstanding, the predominant change in lighting design for interior applications over the last 20 years has been to minimize illumination—in contrast to an earlier philosophy of maximizing illumination. "Prior to the energy crisis from the oil embargo in 1973, which made all energy costs rise dramatically, lighting engineers designed environments for maximum illumination for any tasks that might be performed," says Brainard. "But after 1973 the goal became the minimum effective illumination for the specific activities of a given environment."

Perhaps nowhere are the effects of the reduction in interior illumination levels more obvious than in the control rooms of various complex industrial and technical operations—from oil refineries and communications centers to space launch and mission control centers, power plants, chemical plants, and security monitoring centers. In most cases, the lighting levels in these facilities have been successively lowered in recent years not to save energy but to reduce glare and improve contrast on the increasing numbers and types of

UTILITY TRIES BRIGHTER LIGHT IN A CONTROL ROOM **San Diego Gas & Electric is believed to be the first U.S. utility to use a computerized overhead lighting system in a power plant control room to help operators adapt to shift work. Installed by Light Sciences, Inc., of Massachusetts, the system can vary light intensity (up to about 5000 lux) on the basis of information given to it about the work schedules and biological rhythms of individual operators. Thus the lights, which are designed to minimize glare on computer displays, would be brightest at the start of an overnight shift. In addition, operators are trained in techniques to help them adapt to variable shifts.**

Alan Decker/NYT Pictures

computer screens and digital displays that are vital to control room operation.

Control rooms illustrate just how low lighting levels can get when factors other than human biology or physiology dominate lighting design. The guideline issued by the Nuclear Regulatory Commission for background illumination in nuclear power plant control rooms, for example, is 100 to 500 lux. Brainard notes that while these levels may be adequate for vision, they may not be optimal for worker alertness.

Ironically, most control-room-type facilities are staffed around the clock, which means that two-thirds of the time the operators on duty are working evening or overnight shifts, making them particularly susceptible to the disruption of body rhythms.

There are numerous studies showing that some shift workers have more health problems than day workers. And there is strong statistical evidence that the disruption of sleep and body rhythms can decrease the alertness and impair the performance of shift workers so that they are at higher risk of human error.

The OTA's September 1991 report on biological rhythms noted the recent advances in neuroscience indicating the adverse consequences for shift workers of extended disruption of their biological rhythms. The study examined how those effects can interact with other factors—such as the fatigue and sleep loss that often accompany shift work—to the detriment of the workers' health and performance. Noting that the United States is one of the few industrial nations that lack specific regulations covering shift workers, the study outlined a number of steps—including mandated changes in shift work scheduling practices, and education and light therapy for workers—that warrant consideration by policymakers.

To highlight the variety of settings for shift work and the special considerations that many of these settings involve, the OTA study included three case studies: registered nurses and resident physicians, the military, and nuclear power plant control room operators. Because of the potential implications for public and worker safety, nuclear plant operators have been a particular focus of concern. Anticipating this issue, EPRI published a report in early 1990 that provides guidance to utilities in managing all of the factors that affect the alertness and health of these operators. While proper scheduling practices remain the key variable in shift worker alertness, the EPRI study, like the OTA report, acknowledged the importance of lighting among other control room factors.

The EPRI study pointed out that although visual discrimination may be enhanced by the use of low ambient lighting levels to provide adequate contrast for computer screens, "there may be a substantial trade-off with respect to maintaining optimal operator alertness." On the other hand, the study noted, excessively bright lighting levels in the control room can lead to eye fatigue and, in turn, to reduced alertness.

Clearly, the answer to optimal control room performance is more complicated than simply cranking up the lighting levels. The recent melatonin studies, including EPRI's, suggest that additional research is needed to establish lighting approaches that effectively serve both visual and biological needs. EPRI's Nuclear Power Division is currently considering such research.

Meanwhile, San Diego Gas & Electric Company reports positive results from the first-ever utility trial of bright-light therapy for control room shift operators. Begun last January, the six-month trial used overhead light panels to provide about 5000 lux to operators at two units of the utility's four-unit South Bay fossil plant. Although the trial ended in July, the systems—installed by Light Sciences, Inc., of Massachusetts—remain in operation, according to environmental manager Stephen Allman, who was plant manager at the start of the test.

In these systems, software programmed with information about the biological rhythms of individual operators and their schedules automatically adjusts the overhead illumination—making it brightest, for example, at the start of the graveyard shift (11:00 p.m. to dawn). The lights are arranged to minimize glare on computer displays. The operators, who have been trained in how lifestyle choices like sleep and diet can affect body rhythms, continue to work the conventional seven-days-on, two-off rotating shifts. Allman says that the workers who report getting the most benefit from the light therapy in terms of improved sleep or alertness are those who use the full range of new techniques for adjusting to shift work.

Illumination in a new light

As utilities become more familiar with the recent research on control room lighting (including the bright-light trials at San Diego Gas & Electric) and as recent advances in the neuroscience of light become more fully appreciated, the use of bright architectural lighting for improved alertness and performance is likely to grow. Continuing studies, such as those directed by George Brainard at Jefferson Medical College to determine the minimum lighting level necessary to produce a human biological response, will help sharpen the research, which is at the boundary between biology and engineering.

"Once minimum lighting levels for promoting beneficial human response are identified, the long-term biological and performance effects on humans will be studied in laboratory experiments and in controlled field tests," says EPRI's Thomas Schneider. "This research will support the development of standardized, energy-efficient lighting protocols and technologies to enhance human performance through circadian stimulation. In the long run, the results are likely to lead to improved illumination strategies for power plant control rooms, offices, hospitals, and other work environments." ■

Further reading

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Background information for this article was provided by Thomas R. Schneider, Office of Exploratory & Applied Research.

Keith Stoma knew it was just a matter of time before the zebra mussel found its way into the southern stretches of the Mississippi River. At an EPRI conference three years ago, he learned that the resilient and prolific freshwater mollusk—a native of western Asia—has a knack for getting around, having already traveled through Europe, across the North Atlantic Ocean, and into the Great Lakes region of the United States.

In the years since the EPRI conference, Stoma, a senior environmental analyst for Gulf States Utilities, has kept tabs on the mussel's progress. On the basis of his predictions, Gulf States implemented a formal zebra mussel monitoring program at the River Bend station, some 100 miles north of New Orleans, in January of this year. Sure enough, on May 14 some tiny mussel offspring (called veligers) drifted from the Mississippi into the water intake system of the 936-MW nuclear plant. They were snagged by a plankton net installed as part of the monitoring program. "I knew they'd be here; it was just a matter of when they would arrive," says Stoma, noting that the sight of those first, ominous veligers was not a pleasant one. "It's like finding out you've got some kind of horrible disease."

Indeed, since the mid-1980s, when the zebra mussel first arrived in this country, infestation has spread like some sort of modern-day industrial plague. The striped bivalve has invaded all types of operations that draw water from infested sources, including municipal water supply companies, automobile and chemical manufacturing plants, food processing facilities, and, of course, power plants.

Averaging only 1 inch long, zebra mussels settle in dense populations, numbering into the tens of thousands and measuring up to 4 inches thick. Given the female mollusk's ability to produce between 10,000 and 1 million eggs per year, problems can develop quickly. The bivalves have become a nuisance at fossil fuel, nuclear, and hydropower plants alike, fouling water intake systems, plugging condensers, blocking service water lines, and causing plant deratings. They even managed to shut down a municipal water system in Monroe, Michigan. The federal Aquatic Nuisance Prevention and Control Act of November 1990 estimates that the critters will cost businesses and communities $5 billion by the year 2000.

Spreading fast

Introduced to Lake St. Clair about 1986 (biologists say the first intruders were probably discharged with the fresh water from the ballast of a European ship), the zebra mussel has since infested all of the Great Lakes and several major rivers in the central and eastern portions of the United States. The sighting at Gulf States Utilities in May marked the southernmost point of the mussel's U.S. migration—some 50 miles deeper into the South than experts had predicted two years ago, when the *Journal* first reported on the invasion (see the September 1991 issue, p. 12). Eastward, the mussel has forged into the Hudson and as far along this river as fresh water can take it—some 70 miles past Albany. Toward the west, it's pushed about 35 miles into Oklahoma via the Arkansas River.

Biologists think that the mollusk's inability to survive in temperatures above 90°F will prevent it from venturing too deeply into the waters of the steamy South, and that its intolerance of temperatures lower than 32°F will keep it from traveling farther northward than central Canada. Still, the zebra mussel's potential domain includes fresh waters throughout two-thirds of the United States, as well as in the southern portion of Canada. This region encompasses 70% of U.S. power plants.

Tony Armor, director of EPRI's Fossil Power Plants Department, urges utilities to be on their toes. "The power plants most susceptible to immediate impact—that is, occurring within the next few years—represent 158,000 MW, or 23% of all installed power in the country," he says. "These 162 plants are located on river systems known to have zebra mussels. This is not even counting the rivers the mussels haven't reached yet."

Fifty-three of these power plants—large facilities, representing 7% of installed U.S. capacity—are located in the Great Lakes region, the area to which the zebra mussel was first introduced. The remaining plants are located on the major river systems connected to the Great Lakes, including the Mohawk-Hudson, Allegheny, Susquehanna, Ohio, Mississippi, and Illinois. So far, sightings have been reported on all of these rivers but the Allegheny. (For further details, see EPRI's "Zebra Mussels: The Industrial Impact," presented at the third international zebra mussel conference in February 1993. This and other selected conference papers appear in a recently published report, TR-102077.)

Barge-bound

John Tsou, an EPRI research manager responsible for macrofouling control technology, points out that river barge traffic has contributed significantly to the spread of the zebra mussel. Just weeks after spawning, the mussels sprout byssal threads, which allow them to cling to hard surfaces, such as the hulls of barges. "The barge traffic is a big issue," says Tsou. "This is what brought them from Lake Erie to Lake Michigan, and it's what got them into Lake Superior and other isolated spots. The barge traffic is also what's allowing infestation to spread upstream." Upriver transport is crucial to the mussels' movement into the western United States, since virtually all points of infestation lie downstream from the major rivers of the West.

Biologists who studied mussels populating the hull of one barge dry-docked on the Illinois River last winter determined that it had traveled some 15,000 kilometers from the time it contracted its first striped mollusk. This means that the colony on the barge may have showered

UPDATE

ZEBRA MUSSELS
The Assault Continues

THE STORY IN BRIEF Over the past seven years, zebra mussel infestation has spread relentlessly, fouling up utility cooling intakes and other industrial operations that draw fresh water. The striped invader has flourished in all of the Great Lakes and most of the major river systems east of and including the Mississippi. It has also migrated much deeper into the South than experts anticipated and is making its way westward. Now biologists have turned up a separate, look-alike species they fear may be just as destructive. EPRI is continuing its work to improve control techniques and has published a comprehensive monitoring and control guide that outlines the best practices currently available for dealing with the mussel problem.

by Leslie Lamarre

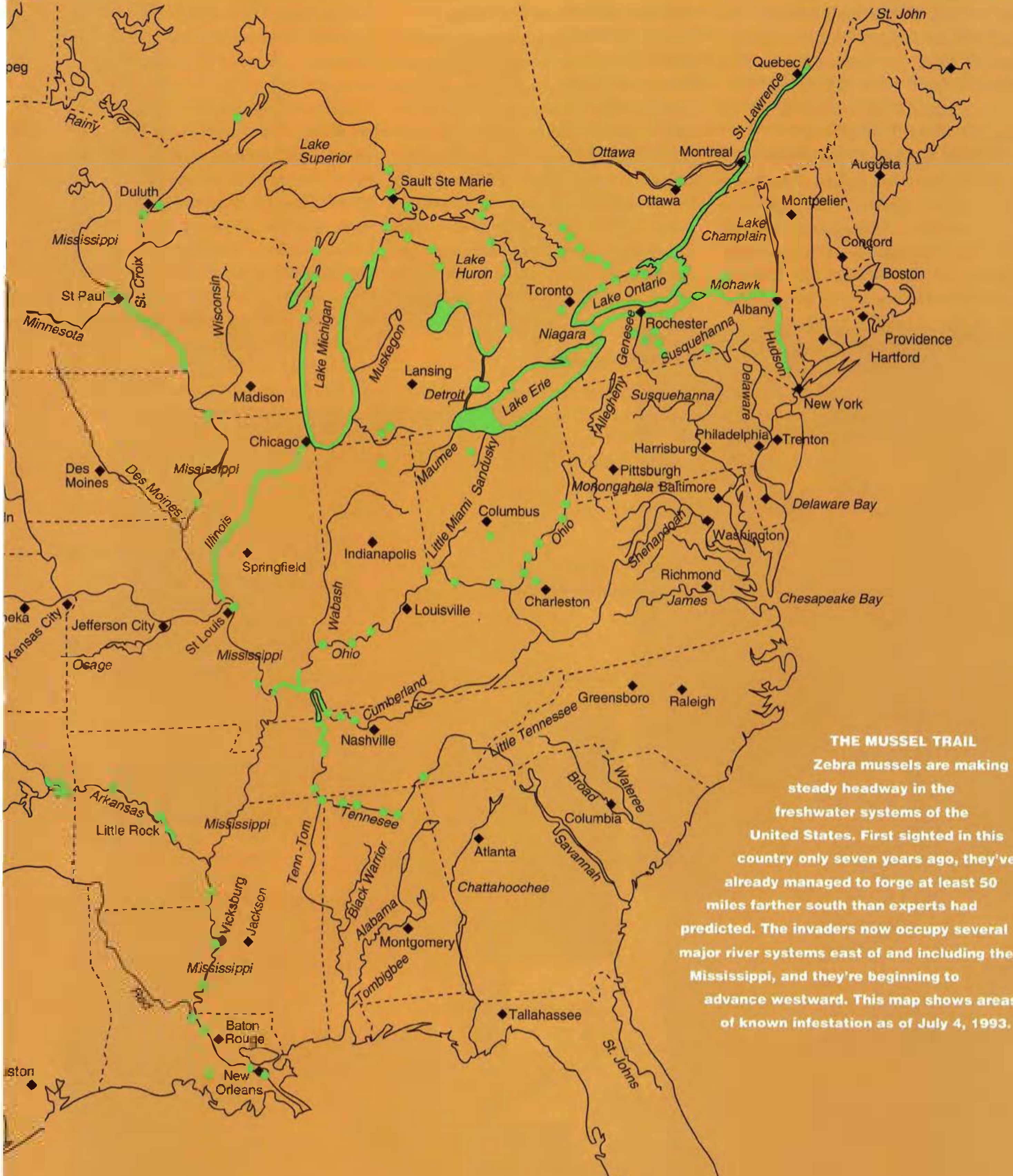
the waterways along the craft's itinerary with large numbers of zebra mussel veligers. (The minuscule veligers drift with water currents until they develop byssal threads.) "That's a lot of infestation to spread," says Tsou. "And this one barge is representative of hundreds or thousands of other barges on U.S. rivers with similarly extensive travel schedules."

Some utilities even report contracting zebra mussels from the very barges that deliver coal to their doorsteps. Joe Johnson, an environmental specialist for the Tennessee Valley Authority, says that's probably how TVA's Shawnee plant on the Ohio River in Kentucky got its first zebra mussels. Shawnee's coal unloading dock is located within a couple of hundred feet of the plant's intake system. The barges, which load their coal in Kentucky and Ohio, travel through infested waters on their way to the utility. "You can see the mussels all over the bottoms of these barges," says Johnson. The Shawnee plant is one of more than a dozen locations along the Ohio where zebra mussels have been sighted.

Getting a grip

Utilities experienced with the bivalve say keeping well informed is the first step toward effective zebra mussel control. One resource many of them have found useful is the zebra mussel information clearinghouse in Brockport, New York. Organized by the New York Sea Grant Extension and funded by Empire State Electric Energy Research Corporation (ESEERCO), EPRI, and others, the clearinghouse tracks the latest news on the troublesome mollusk and offers a comprehensive library of data on the pest. This information is also available through EPRINET, the Institute's on-line information system.

To help further spread the word on zebra mussels, EPRI cofunds what has become an annual, multi-industry, international zebra mussel conference. This event is typically scheduled during the winter, long enough after the warm summer months—the bivalves' peak spawning season—that utilities and other industries can report on their infestation and control experiences over the year and that indus-



THE MUSSEL TRAIL
Zebra mussels are making steady headway in the freshwater systems of the United States. First sighted in this country only seven years ago, they've already managed to forge at least 50 miles farther south than experts had predicted. The invaders now occupy several major river systems east of and including the Mississippi, and they're beginning to advance westward. This map shows areas of known infestation as of July 4, 1993.

trial, government, and academic researchers can present their latest findings. The zebra mussel conference is an increasingly popular event; the conference this past February drew about 600 people. Next year's conference, the fourth, is set for March in Madison, Wisconsin.

"Electric utilities have been very much on top of the zebra mussel issue," says Chuck O'Neill, director of the zebra mussel information clearinghouse. "Lots of work has been sponsored by individual utilities, and organizations like EPRI and ESEERCO have done a good job of bringing all the information together and getting it to the right people." To coordinate its research, EPRI maintains an interdivisional zebra mussel task force whose members—Tony Armor, Bob Edwards, Jack Mattice, Michael Miller, and John Tsou—represent three of EPRI's six technical divisions. The task force is aided by a 25-member utility advisory group, which helps ensure that the Institute's research addresses member utilities' needs.

Aside from keeping informed, utilities located on infested waterways should also initiate monitoring programs as early as possible, experts advise. As Stoma of Gulf States Utilities points out, the mussels are much easier and less costly to manage in their early, veliger phase of development. Shortly after the sighting at the River Bend station, Gulf States implemented a temporary chlorine injection system to control the mollusks. A permanent system is expected to be installed by the end of the year.

Chemical quandary

The use of chemicals other than chlorine as a control option is becoming increasingly difficult for utilities to implement because of environmental concerns. "Overall, the Environmental Protection Agency is being strict about using chemicals," says Peter Howe, the EPA's power plant expert for the Great Lakes region. "The use of chemicals for controlling zebra mussels is becoming even more of an important issue to the agency."

As Howe explains, the increased concern is due to the larger number of power plants implementing control measures. He offers the example of the Ohio River, where there are 38 power plants. "If all these facilities employed chemicals for mussel control, the ecological impact of the repeated release of such large quantities could be great," he says. Chemicals other than chlorine are the main concern, since the EPA is already familiar with chlorine and has the data it needs to regulate it. Still, the use of chlorine is also monitored closely. "The use of any biocide, including chlorine, must meet all state water quality standards," points out Howe. "The EPA is encouraging utilities to look into alternatives to using chemicals for control."

Indeed, as Bob Edwards of EPRI points out, a proprietary molluscicide that EPRI developed for use against the zebra mussel, and that proved effective during a full-scale test at Centerior Energy last summer, is unlikely to be commercialized in the near future. Edwards, who managed the three year project, notes that there have been recent indications that the EPA may require additional data on chemical compounds other than chlorine and perhaps bromine. "Such uncertainty in the regulatory process inflates estimates of the cost and time required to register any new product," says Edwards. "In turn, this effect increases the difficulty of attracting a potential commercializer for EPRI's proprietary molluscicide."

But the use of chemicals is just one potential option available for controlling ze-

MUSSELS, MUSSELS EVERYWHERE **No hard surface submerged in fresh water appears to be off-limits to zebra mussels. They use their hairlike byssal threads to attach themselves to whatever they can find, including each other.**

Carpeting utility machinery

Clogging up a power plant's condenser tubes

A crayfish under siege

bra mussels. Others include thermal treatment, in which hot water is recirculated through the condenser system and into the intake structure; the coating of intake system components with slick materials that reduce or weaken mussel attachments; and the physical removal of the mussels (by shoveling, vacuuming, high-pressure water jets, and other means). Each of these options is explained in detail in EPRI's *Zebra Mussel Monitoring and Control Guide* (TR-101782), produced by EPRI's zebra mussel task force.

Released early this year, this 700-page resource offers a comprehensive compilation of U.S. and European practices as of the end of 1992. It also includes innovative approaches to mussel control that are still under study, such as the use of ultraviolet light, acoustics, and electricity. The guide is intended to be a living document, says Edwards, who managed its production. "It will be revised and updated as we get feedback from utilities and the broader research community. We encourage all members who have freshwater intake systems with the potential for infestation to order a copy."

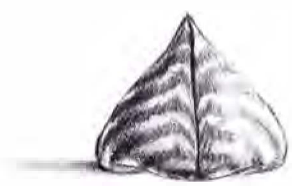
Hot stuff

In the meantime, EPRI continues its pursuit of improved control methods. Research is under way on a new thermal treatment process, a simplified procedure that appears to be less time-consuming and less energy-intensive than the conventional procedure, with a reduced ecological impact. "This new technique for thermal treatment looks very promising," says John Tsou, manager of the project.

Tsou points out that one problem with the current thermal treatment procedure is that only a small number of plants are designed to allow for the recirculation of hot water. These are plants with de-icing systems—mostly fossil and nuclear power plants located in the Great Lakes region. The other problem is that a plant must operate at reduced output or even be shut down in order to perform the recirculation procedure.

By contrast, the new process under development by EPRI employs targeted thermal treatment, focusing heat on the problem areas only. It does not require a plant shutdown, nor does it need a special system for water circulation—a feature that makes it feasible for all types of plants. The first phase of the project to develop the new process, which got under way this summer at EPRI's High-Sulfur Test Center, entails a feasibility study and laboratory testing. EPRI expects to start the demonstration phase by the middle of next year and is now seeking host utilities.

For the most effective control program, many utilities employ a combination of proven methods. But whatever solution utilities opt for isn't likely to be cheap. They have already spent millions of dollars in the war against the resilient mollusk. And they aren't alone. The city of Buffalo has proposed a 15% increase in water rates to deal with the problem.



Zebra mussel

Quagga mussel

DOUBLE TROUBLE **It appears that a distant cousin of the zebra mussel has dropped in for a lengthy visit. The quagga was first spotted in U.S. waters in 1990, about four years after the zebra mussel. Although to the layperson the two mollusks look much the same, biologists say that they are separate species. The key physical difference is that the zebra has one flat side, unlike the quagga. Utilities are paying close attention to research exploring other differences, since it is not yet known whether control methods used against the zebra will be effective against the quagga.**

Trouble ahead

Just when it seems that utilities have demonstrated a reasonable amount of control over the striped invader, another related nuisance has cropped up—the quagga mussel. Named after an extinct African relative of the zebra, the quagga mussel looks much like a zebra mussel to the untrained eye. But biologists say it is a separate species. The main physical difference between the two species is that the zebra, unlike the quagga, has one flat side. Also, the quagga tends to be slightly larger.

First detected in the Great Lakes region in 1990, the quagga is still something of a mystery to researchers, who continue to explore the differences between the two bivalves. From what has been learned so far, the quagga appears to have a higher salinity tolerance than the zebra and seems to survive at greater water depths. Understanding such seemingly subtle biological differences may be crucial to determining whether the control methods used against the zebra mussel will be effective against the quagga. To help answer that question, EPRI has proposed a comparative study of the two species. This proposal is currently under review.

In the meantime, utilities experienced with the problem are eager to share their words of wisdom with others. "My best advice is to be very proactive and start some sort of monitoring program before these things appear, because—as EPRI says—they are like a silent invader," says Keith Stoma, referring to the title of a video EPRI produced on the zebra mussel (EA91-03). "These guys won't rear their ugly little heads out of the water. You really have to go look for them so you can catch them before they cause any problems." ■

Background information for this article was provided by Bob Edwards, Nuclear Power Division; Tony Armor and John Tsou, Generation & Storage Division; and Jack Mattice, Environment Division.

ELECTRIFICATION FOR DEVELOPING COUNTRIES

by Dr. Hisham Khatib

The future of developing nations hinges to a large extent on the growth of electrification, according to Dr. Hisham Khatib of the World Energy Council's committee for developing countries. But in trying to make electricity widely available, the poorer nations of the world face serious barriers, including capital shortages, institutional weakness, and a pressing need for technology transfer.

In a speech at EPRI's international symposium on global electrification, Dr. Khatib discussed these and other key energy issues for developing countries and prescribed a strong helping hand from the industrialized world.

Electricity has become a most important ingredient in human life, absolutely essential for modern living and business. The disruption of electricity service, even if transient, can create havoc in cities and urban centers and tremendous inconvenience in our personal lives.

In a very real sense, electricity is the lifeblood of progress in the industrialized world. But even today, almost 2 billion people living in developing countries—about a third of the world's population—still have no access to a reliable electricity source. This lack of access is a major impediment to sustainable development in these countries and to the harmonious progress of global society. Investment in further electrification will clearly be necessary for developing countries to make progress in the modern world.

The nonavailability of electric power handicaps the social, economic, and cultural development of nations. Its availability is a prerequisite to attaining the minimum levels of human welfare and quality of life in any country or society. Electricity improves health standards and assists in education. In homes it provides for comfort, food preservation, lighting, and access to the media and mass entertainment. It assists in overcoming poverty by promoting people's expectations for a better life and by creating jobs and commercial opportunities that generate self-sustained, long-term economic growth.

The idea that all nations on earth have a right—and should have the means—to pursue these benefits will become increasingly important in a world where opportunity is disproportionately divided between the industrialized countries of the northern hemisphere and the poorer nations farther south. Wider access to electricity in developing countries will be a key requirement for narrowing the north-south gap.

Population, prosperity, and power

That gap is indeed substantial. As Table 1 shows, with a population of around 4 billion, the more than 120 developing countries account for slightly over three-quarters of the world's population. However, the contribution of these countries to the world's generated income is only 13%, against 78% for the high-income industrialized countries. On a per capita basis, this amounts to a gap in income of about 27:1 between the affluent and the poorer countries. The disparity can be seen in national electricity generation as well, with the high-income nations producing and consuming about three-fifths of the world's electricity. In fact, of the 2 billion people doing without electric power, about a billion have no access to commercial energy in *any* form—not even gasoline or diesel oil. These people operate entirely on wood fuels and other biomass resources.

Thermal facilities—primarily coal-fired plants—produce about 70% of the electricity in developing countries, with hydroelectric plants contributing a very significant 29%. Only about 1% comes from nuclear facilities. Hydropower has great potential for further development in these countries, since only about 9% of the resources have so far been exploited. By comparison, over two-thirds of the total hydro resources in the United States—and virtually all of the high-capacity sites—have already been tapped.

Unfortunately, hydro facilities are dreadfully large and expensive, requiring a great deal of infrastructure and capital investment, which many developing countries are short of. The other drawback is that although the hydro resource may be huge, it is often located far from the center of demand. In areas such as central Africa, the electricity may need to be transmitted thousands of kilometers via extra-high-voltage lines. Such delivery systems, of course, are also extremely expensive. (There has been some talk recently of using hydroelectric power to produce hydrogen gas, which could then be transported to the point of use and converted back to electricity. This idea might be of great interest in the future, but we expect that coal will continue to be the primary source of electricity in developing countries for at least the next few decades.)

Problems of power delivery actually have deeper consequences for electrification than the hydro example might imply. Power plants in developing countries have typically been sited near urban centers to support business and high-density population. But the majority of the people in these countries live in rural areas; to serve them would require the development of extensive distribution systems to deliver very limited amounts of energy. That makes for a very high real cost of electricity and is why rural areas have generally not been electrified (see Table 2). The situation also has the unfortunate effect of encouraging migration from rural areas to cities, which further burdens the urban infrastructure and leads to public health and welfare problems. If electricity is to truly promote human progress in developing countries, the problem of rural supply must be addressed.

The orthodox approach of central station generation, which is ideal for industrialized countries and urban centers, may not make sense for rural areas, where the demand per consumer is only a small fraction of a kilowatt. We should take a close look at distributed technologies that can economically serve small villages or even individual consumer loads. Small diesel sets can be an answer to many needs, but they demand a regular supply of fuel, spare parts, and skilled maintenance, which are not always available. The exploitation of local mini- and microhydroelectric power is another option where hydro resources are available.

"In a very real sense, electricity is the lifeblood of progress in the industrialized world. But even today, almost 2 billion people living in developing countries—about a third of the world's population—still have no access to a reliable electricity source. This is a major impediment to sustainable development in these countries."

Photovoltaic solar cells for use at individual houses or in small communities are a very important development that warrants particular attention. PV cells generate electricity directly from sunlight, and because they need no fuel and practically no maintenance, they are technically ideal for low-power rural applications. A setup that can supply the needs of a small house, including wiring and a storage battery, can now cost as little as $600, and the costs are still dropping. It has been claimed that 25% of the rural population with no access to electricity could be economically supplied this way. We must continue to investigate this and other unorthodox, local, or individual approaches.

Attracting capital

Because electricity is so sparsely available in developing countries today, the demand for it there is increasing about three times as fast as in the industrialized world. If that trend continues—and it will—by 2020 the developing countries' electricity consumption will increase from less than a quarter of the world's supply to about half. This means that those countries will have to build some 3000 GW of capacity and invest something like $6 trillion on electricity supply over the next 30 years—a tremendous challenge for capital-constrained nations. This level of investment would amount to almost 20% of what we call gross capital formation—the money that a government invests in its infrastructure, education, and training to improve the future economic outlook. Such a high percentage for electric power development, 10 times as high as in some

Table 1: Global Income and Electricity Balance

	Population (1990)		GNP (1990)		Per Capita Income (1990)	Electricity Demand (1992)	
	Millions	% of total	$ trillions	% of total	$	TWh	% of total
High-income countries*	900	17.0	16.2	77.9	18,140	7,300	59.3
Eastern Europe†	400	7.5	1.9	9.1	4,750	2,250	18.3
Developing countries	4,000	75.5	2.7	13.0	675	2,750	22.4
Total world	5,300	100.0	20.8	100.0	3,936	12,300	100.0

Sources: World Bank Atlas (1992), United Nations Development Program (1992), International Atomic Energy Agency (1992).

*Includes newly industrialized countries and all OECD countries except Turkey.

†Includes the Commonwealth of Independent States and other countries now in transition.

industrialized countries, is particularly burdensome for developing countries because of the severity of other pressing social priorities, including health, education, and employment.

Some of the capital required can be attracted from local sources. However, foreign currency will also be needed, since electricity systems typically involve a lot of imported equipment; in countries that do not have enough indigenous energy resources, fuel must be imported as well. Most developing countries have to resort to aid and debt to meet these needs. The amount of aid—in the form of grants to the energy system—has not been large, so loans have been the rule.

But to build electricity systems on the scale required for economic evolution, developing countries will need to attract more local capital and, especially, foreign investment by industrialized countries. To do this, they will have to modify their capital markets, legal framework, and institutional structures toward a more commercial outlook. Build-operate-transfer projects and similar arrangements have been tried but so far have been very limited because of institutional problems. And most of the institutional barriers are a function of the dominant role of government in the electricity sector.

In developing countries, electricity investment is so large and risky that only the government can afford it. Although power distribution is sometimes undertaken by the private sector, the government virtually always operates as the regulator, majority owner, and manager of the electricity system. The government sets prices to reflect its social and industrial policies, and these prices are in most cases subsidized. Governments will continue to dominate the energy sector in many developing countries for decades to come, mainly because the financial markets in those countries have not been developed enough to take a sizable ownership role in such a capital-intensive industry. Nevertheless, it is in the countries' long-term self-interest to limit government control and encourage free market development in order to improve the performance of the electricity sector.

There are several ways to approach the process of changing institutional roles. Governments can enhance the role of the private sector through fiscal measures, policies, and legislation that will both mobilize local capital and attract foreign investment. Alternatively, they can establish government-owned but autonomous companies and corporations to run the energy sector. Such institutions should be given the independence to perform as private-sector concerns—with accountability for performance, with employee pay set by market forces, and with employment rules similar to those used in the private sector. The development of manpower and man-

"The orthodox approach of central station generation, which is ideal for industrialized countries and urban centers, may not make sense for rural areas, where the demand per consumer is only a small fraction of a kilowatt. We should take a close look at distributed technologies that can economically serve small villages."

Table 2: Population With Access to Electricity (1990)

	Percentage of Population With Electricity	Percentage of Population That Is Rural	Percentage of Rural Population With Electricity
Industrialized countries	100	27	100
Developing countries			
China	75	66	63
India	25	73	10
Sub-Saharan Africa	19	69	5
Least-developed	13	80	5
Other	78	45	63
Total developing countries	52	63	40
Total world	63	55	54

agerial capabilities will be a key factor. Good workers and managers are more likely to develop in competitive markets, where promotion and remuneration depend on performance. Because government-operated electricity institutions often lack these incentives, a shortage of capable management is a bottleneck in development for many poorer countries.

Restructuring toward a market-based system is not easy, particularly with the presence of democratic institutions in developing countries that are anxious, more often than not, to use government control to protect vested public rights, such as subsidies. Most developing countries subsidize electricity in order to stimulate business and improve the quality of life, and the price of power to the user is typically below the actual production cost. Unfortunately, subsidies have a negative influence on development by encouraging overuse, waste, and misallocation of resources. When prices are kept artificially low, there is less incentive to pursue efficiency or system improvements. This is a primary reason for moving away from a government-controlled and -subsidized system to a market-controlled structure.

Of course, the interests of the less-privileged portion of the population should be protected when such changes are made, but this can be accomplished through a tiered structure rather than across-the-board subsidization. For instance, the first slice of electricity consumption—say, the first 100 kWh a month—would be sold at a subsidized price that can be afforded by the low-income group; higher slices of consumption, typically bought by the higher-income group, should reflect the real cost of power, with an increasing tariff to discourage waste. Business-sector subsidies to encourage the growth of export industries could be in the form of direct payments in proportion to the actual exports and not through electricity price subsidies. Such arrangements would ultimately ensure the optimization of production facilities and the reduction of production costs. They would also slow the current rampant growth of electricity demand and reduce the pressure on a government to invest in new facilities.

"What's needed in developing countries is capacity building in the broadest sense of the term: the building of institutional strength, employment, personnel and management expertise, technical capability, local economies, and export markets. These are assets that can be built on, not just consumed."

Need for technology transfer

Assuming that the government of a developing country can attract outside interest in enhancing its electric power system, what form should assistance from the industrialized nations take? Technology transfer is crucial. Developing countries cannot afford to redevelop advanced electrical technologies that are already available in the industrialized world: their contribution to innovation and to the development of new technologies is necessarily limited by a shortage of skilled manpower and resources. These sophisticated technologies must be imported and adapted to the circumstances and needs of the developing nation. Certainly this is partially a matter of capital investment. But too often, a foreign company or contractor will be imported to plan a project, design it, build the facility, and even operate it, without any real connection to the host country. This is not technology transfer, and it is not the way to change and improve the overall picture.

The best way to make foreign assistance produce lasting benefits is not the execution of turnkey projects but the development of joint ventures that involve local expertise. The developing country should participate to the best of its ability in all aspects of the project, including planning, construction, plant operation, and the production of parts that can be manufactured locally (with quality control assistance from the manufacturer or the industrialized partner). Of course, some of the needed equipment, such as turbine generators and control and monitoring equipment, must come from highly sophisticated factories. However, a lot of components—transmission and distribution equipment or pipework, for example—are standard items that can be produced locally by medium-sized developing countries. That should be encouraged.

Developing countries have to help themselves. What's needed is capacity building in the broadest sense of the term: the building of institutional strength, employment, personnel and management expertise, technical capability, local economies, and export markets. These are assets that can be built on, not just consumed. But this kind of capacity building—essentially increasing local capabilities through joint ventures with industrialized partners—means a change of mentality and a political commitment by the government to institutional reform. The governments of developing countries must establish contacts, agreements, and legislation that reflect a new market outlook—one that will attract outside interest and enhance technology transfer.

The environmental agenda

Foreign investors can certainly profit from joint ventures with developing countries if reasonable agreements are reached. But there is another important incentive for the industrialized world to enter into such relationships: environmental management. Electricity production, like many other activities associated with growth and development, can be a source of pollution at the local, regional, and possibly global levels. The hypothesis that carbon dioxide emissions could result in climate changes throughout the world has generated particularly strong international concern in the last several years. This is another issue that leads us back to the north-south gap.

In the past, almost all of the world's pollutant emissions have been produced by the industrialized countries of the northern hemisphere. Yet we can see from our projections that in several decades the developing countries as a group will become major polluters too. While this is largely a matter of population growth and a steeper ramp of industrial development, other factors are also at work. Capital and technical limitations force poorer nations to make do with older, dirtier, and less-efficient energy production technologies; the use of environmental cleanup equipment is not as widespread in developing countries as in the rest of the world. And developing countries will always use indigenous fuel resources—often coal—before importing cleaner, more-expensive fuels.

> "It is important for the world at large to realize that developing countries do not yet place global environmental issues high on their list of priorities. They are much more concerned with basic challenges—supplying food and other daily needs, fighting poverty, improving their lot, and seeking growth at almost any price."

I think it is important for the world at large to realize that developing countries do not yet place global environmental issues high on their list of priorities. They are much more concerned with basic challenges—supplying food and other daily needs, fighting poverty, improving their lot, and seeking growth at almost any price. Concern about pollution, when it is an issue, is typically focused on problems at the local level. A shortage of financial and energy resources is already imposing severe limitations on the economic development of these countries; they are unlikely to embrace any global environmental effort that imposes further limitations on their meager finances or delays their development. That is why, for example, southern Asia and China will continue to use indigenous, low-quality oil and coal, regardless of the significant environmental impacts that may eventually result from this choice.

Thus if the global community expects developing countries to cooperate in any broad-scale environmental initiatives, it must find an approach that does not impose strain on already-fragile socioeconomic development. Joint ventures, investment in the electricity infrastructure, and the transfer of advanced technologies that promote energy efficiency and conservation are excellent ways of accomplishing this goal. The bottom line is that developing countries will need to be helped by means of capital and technology to play their role in global environmental stewardship. In the longest view, this may be the most compelling reason for the industrialized world to increase its investment in developing countries. ■


McLEARN


MILLER


SCHNEIDER


EDWARDS


TSOU


KHATIB

Digging Into Pollution Prevention (page 6) was written by Leslie Lamarre, *Journal* senior feature writer, with background information from two members of the Environment Division.

Mary McLearn, manager for hazardous and solid waste, joined EPRI in 1984. Before that, she was a project manager at Rockwell International's Environmental Monitoring and Services Center. Her other experience includes four years as an assistant professor of chemistry at Colgate University. McLearn has a BA in chemistry from Skidmore College and a PhD in inorganic chemistry from the University of Kansas.

Michael Miller, manager of the Waste & Water Management Program, joined EPRI in 1980 after two years with Pacific Gas and Electric, first as an in-house advisor on air quality and then as administrative assistant to the vice president of planning and research. Earlier he was an environmental analyst with URS Corporation for four years and an air quality analyst with Northern States Power for one year. He has a BS in zoology and an MS in human physiology and environmental studies from the University of Wisconsin at Madison. He also holds a master's degree in public health from the University of Minnesota. ■

Human Performance in the Spotlight (page 14) was written by Taylor Moore, *Journal* senior feature writer, with background information from executive scientist **Thomas R. Schneider,** who comanages exploratory studies in the Office of Exploratory & Applied Research. Schneider joined EPRI in 1977 after five years as a research physicist with Public Service Electric & Gas in New Jersey. From 1985 to 1987, he served as president of the nonprofit Lighting Research Institute. Schneider earned a BS from Stevens Institute of Technology and a PhD in physics from the University of Pennsylvania. ■

Zebra Mussels: The Assault Continues (page 22) was written by Leslie Lamarre, *Journal* senior feature writer, with technical information from two EPRI staff members.

Bob Edwards, manager for performance and reliability in the Nuclear Power Division, came to EPRI in 1990. Earlier he spent 15 years at Bechtel in power plant engineering design and project management. He also served as a presidential exchange executive with the U.S. Department of Energy for one year. He has a BS from Tuskegee Institute and a JD from Golden Gate University.

John Tsou is manager for performance and availability in the Generation & Storage Division. Before joining EPRI in 1985, he managed an engineering department at McQuay, Inc., for nine years. He also held engineering positions with other U.S. firms, including Riley-Beaird, Colt Industries, and Aqua-Chem, and was a marine engineer with Marine Industries in Hong Kong. He received a BS in marine engineering from the Taiwan Maritime College. ■

Electrification for Developing Countries (page 28) is based on a speech by **Hisham Khatib** at a recent EPRI symposium, "Global Electrification: Promise for the Future." Khatib is a consultant on energy and development issues, specializing in electricity, the energy future, and global environmental impacts. He currently chairs the World Energy Council's Committee on Energy Issues in Developing Countries. From 1984 to 1989, Khatib was the minister of energy and mineral resources for the government of Jordan, and earlier he served as director general of the Jordan Electricity Authority. He holds a BS in electrical power engineering from Ain Shams University in Cairo and a BS in economics and a PhD in electrical engineering from the University of London. ■

Fuzzy Logic in the Utility Industry

Something Fuzzy's in the Air

Some problems in life are ill suited to precision. For example, consider the frustration of having to park a car exactly 6 inches from the curb when "close to the curb" is really where you want to be. Technical problems that require the rapid manipulation of large quantities of data can similarly frustrate a computer set up with deterministic algorithms—especially when uncertainties enter the picture. But an approach known as fuzzy logic can swiftly provide the ballpark answers needed to get the job done, even if uncertainties are involved.

Fuzzy logic emulates the reasoning of the human brain in that it can tolerate imprecision and allow for the mathematical representation of uncertain variables, such as "close" and "far." To date, fuzzy logic has been developed largely for use in consumer electronics products. In one successful application, fuzzy controllers in small video cameras compensate for the typically perceptible shaking in footage shot with hand-held cameras. EPRI believes that there is significant potential for fuzzy logic to solve practical problems in the electric utility industry, and it has launched a two-year project (RP8010-34) to find out more.

Sid Bhatt, manager of the project, says that the science of fuzzy logic must be developed further before it can actually be employed for complex applications in the electric utility industry. In fact, the development of fuzzy logic calculus is one aim of the project Bhatt oversees. A second aim is to identify potential utility applications. Decision making under tight time constraints, equipment diagnosis, and intelligent control systems are just some of the potential areas under consideration. The project is expected to be completed in about one year.

Bhatt says that fuzzy logic has already been used successfully in the electric utility industry in Japan, where in the past four years alone, approximately 350 patents have been sought for fuzzy logic applications. And here in the United States, in a spin-off of Bhatt's project, EPRI has signed a contract with General Electric to determine whether the control of combustion turbines could benefit from fuzzy logic. Specifically, the joint effort is investigating whether fuzzy logic might allow quicker startups, reducing fuel use and minimizing strain on turbine equipment. Another fuzzy logic project at EPRI is seeking to develop a fuzzy controller that will improve the efficiency of the microwave clothes dryer.

■ *For more information, contact Sid Bhatt, (415) 855-8751.*

Polymer Research

From Tires to Cables

What's good for making packages last until they're opened, or even for making automobile tires last 50,000 miles, isn't necessarily what's best for insulating utility cables. After all, the rubber on your car is probably good for only about four years, and the material that goes into throwaway packaging has an even shorter shelf life. Yet since World War II, automobile and packaging interests have been among the prime movers behind research on polymer technology. The utility industry has had no choice but to use the resulting polymers as raw materials for electrical equipment.

Making the best of what they have had to work with, manufacturers for the utility industry have been able to stretch the life of cable insulation to about 7–25 years for medium-voltage cabling. Not bad, until you consider that to be economically attractive, underground cabling should last about four decades without having to be dug up. Unfortunately for the utility industry, this has not been the case because conventional polymers have demonstrated poor resistance to a phenomenon called water treeing, in which water seeps through the insulation, branching into a treelike pattern. Water treeing reduces cable life and can cause premature cable failure.

Getting underground cabling to last through its fortieth birthday—in effect, doubling its current life—is one of the primary goals of EPRI's recently launched project on polyethylenes for high-voltage cable insulation (RP2986-8). The three-year study, conducted by researchers at the University of Tennessee, will take advantage of new developments in polymer technology, says Bruce Bernstein, who is managing the project. "New catalyst technology has changed the way polyolefins are prepared," he explains. "Now we know that by controlling the polymerization technology and the nature of the catalyst, we can control the properties of the polymer. We can alter the density and molecular weight of the material, control the copolymer structure, and hence tailor the insulation properties to meet utility needs."

The researchers aim to provide, by 1996, information to suppliers and producers that will result in longer-life cable insulation usable throughout the entire voltage range. "With this project, we're trying to plug utility users in at the very beginning of a new technology and provide guidance from their perspective early in the game," says Bernstein. "Taking such an approach is the best way for the industry to control its own destiny."

■ *For more information, contact Bruce Bernstein, (202) 293-7511.*

On-site Power

Fuel Cell Demonstration Planned

San Diego Gas & Electric Company is one of a handful of electric utilities that have begun bringing power generation to customers' backyards. The utility, working in cooperation with EPRI, the U.S. Department of Energy, and the Gas Research Institute, expects to have its first fuel cell operating at a San Diego Kaiser Permanente hospital by 1995. The 250-kW natural-gas-fired molten carbonate demonstration plant will operate continuously, providing both heat and electricity for the hospital.

Being designed and built by M-C Power of Burr Ridge, Illinois, together with Bechtel Corporation of San Francisco and Steward & Stevenson of Houston, the unit is one of four U.S. carbonate fuel cell demonstrations either recently completed or planned for the near future. The others are also in California: Pacific Gas and Electric Company's 70-kW fuel cell in San Ramon, completed in 1992; Unocal's 250-kW unit in Los Angeles, planned for 1994; and the city of Santa Clara's 2-MW installation, which should come on-line shortly before the San Diego project.

EPRI has been actively promoting the development of carbonate fuel cells over the past 15 years. "No other generating technology is as capable of meeting the future energy service requirements of California and the Northeast," says EPRI's Rocky Goldstein, manager for fuel cell technology. "Carbonate fuel cells are 60–65% efficient and absolutely clean and quiet, and they can be built in small or big units close to the customer. The technology also enables utilities to avoid costly transmission and distribution system investments, as well as siting and permitting problems. It is so clean that emissions requirements are being waived."

While phosphoric acid fuel cells will be the first commercially available models, carbonate technology has some unique advantages, including higher efficiency and, when integrated with coal gasification plants, greater long-term potential. Goldstein expects that within the next few years increasing numbers of utilities will use carbonate fuel cells as dispersed power generators on or near customer sites. By the end of the decade, he says, this technology should be a cost-competitive, commercially available form of generation.

"San Diego Gas & Electric believes that fuel cells can meet many of its future needs," Goldstein says. "This demonstration is its first step to help make this technology commercially viable."

■ *For more information, contact Rocky Goldstein, (415) 855-2171.*

Monitoring the Performance of Heat Pump Water Heaters

More than 100 commercial customers of Georgia Power Company are getting their hot water from the most energy-efficient technology available today—and are enjoying the added benefit of essentially free supplemental space cooling—thanks to the utility's efforts to demonstrate and promote heat pump water heaters (HPWHs).

Within the next year or so, other utilities looking to add HPWHs as an option that can both build utility load (through increased electricity sales) and reduce a commercial customer's energy consumption for water heating and air conditioning will have the benefit of Georgia Power's experience, including information on HPWH performance. EPRI is working with the utility to monitor 45 systems in Georgia Power's territory.

The utility purchased the units from four major manufacturers for installation at sites ranging from fast-food and full-service restaurants to laundries, bakeries, and school and hospital kitchens. Customers paid for the installation of the heat pump systems, many of which have an evaporator-compressor mounted in a kitchen ceiling with separate storage tanks nearby. The systems extract heat from the air near ovens and other equipment inside a building and transfer it to water in the tanks. In general, HPWHs are about twice as efficient as electric water heating alone and three to four times as efficient as gas water heating.

Although the utility expected that the energy savings from integrating water heating with a heat pump would be the units' key selling point, customers reported a greater appreciation of the practical benefit of spot cooling of kitchen work areas, making them more-comfortable places for employees. "Our customers really like the cooling and miss it if the heat pump is not operating," says Charlie Wall, a Georgia Power team leader for water-heating sales and service. "The heat pump can provide only 4–5 tons of spot cooling, however, and thus may need to be supplemented with air conditioning capacity," he adds. The average payback period for the units tracked under the Georgia Power program was two to three years. Payback times could run three to five years in other areas, depending on the customer application.

According to Karl Johnson, a manager in EPRI's Customer Systems Division, the Georgia Power project has amassed a solid base of high-quality technical data on the application and operation of HPWHs—data that will yield valuable assistance to other utilities planning HPWH marketing programs and will directly benefit EPRI's R&D programs in

water heating. Project results are being incorporated into EPRI water-heating analysis tools, including handbooks and the H●TCALC software.

"The design community will have a high-quality data set that will have water use and water-heating-demand profiles for the different commercial sectors. With our data, utilities will be better able to assess what HPWHs can do in their service areas for their customers. And customers will be able to apply the systems more effectively and have them work even better."

■ *For more information, contact Karl Johnson, (415) 855-2183.*

Puget Demonstrates Soil Cleanup With Thermal Desorption

Cult fans of the television miniseries "Twin Peaks" might recognize the former railyard as the location for the opening scene, in which a central character is found dead. But to Puget Sound Power & Light Company, the site has been a real-life environmental liability—not a problem of its own making but one that it is nonetheless taking responsibility for cleaning up. At the site in Snoqualmie, Washington, the utility and EPRI are cosponsoring the first major utility demonstration of thermal desorption technology for remediating soil contaminated with hydrocarbon compounds.

In thermal desorption, hydrocarbons are separated from soil in a rotary kiln with air as hot as 900°F. Until recently, the process was considered among the highest-cost remediation options, in part because of the limited capacity of systems that could be assembled at a site and the limited levels of cleanup that could be achieved. Today a number of consulting companies offer mobile units that can process up to 50 tons of soil per hour at a cost that can be competitive with other options.

Puget Sound Power & Light faced a costly cleanup at the

Snoqualmie site, where a nonprofit railroad association to which the utility had granted a limited-use permit in the 1950s had stored railroad cars. Motor fuel and lubricating oil had seeped down from collecting pits about 22 feet into a sandy soil layer and spread laterally far afield. "Most of the material had been in the ground so long that the lighter fractions volatilized, leaving the really stubborn long-chained compounds, which were not breaking down any further," explains Barry Lombard, senior environmental scientist for Puget Sound Power. The utility removed 12,000 cubic yards of soil from an area about 60 feet by 300 feet, storing it temporarily on plastic sheets.

After an attempt at bioremediation proved disappointing, a thermal desorption system produced by Tarmac Equipment Company was brought to the Snoqualmie site on several tractor-trailers and assembled by the project contractor. During system operation, soil is loaded into a screening device on the front end, where it is weighed and rocks are removed. Conveyor belts then take the soil into the drying kiln, where the hydrocarbons are desorbed by the heat and separated from the soil. The hot gas is fed into a supplementary-fired afterburner that produces temperatures of 1500–1600°F for almost complete chemical destruction. The gas is then cooled in a heat exchanger before being sent through a baghouse that collects any remaining particulates.

According to Ishwar Murarka, manager of EPRI's Land & Water Quality Studies Program, the Institute's joint sponsorship of the estimated $1 million demonstration project reflects the value to the industry of Puget Sound Power's experience—both in using a technology that is new to utilities and in remediating a site with characteristics similar to those at other utility sites. Results of the work, much of which was concluded this summer, are expected to have particular relevance for other utilities weighing soil remediation options, especially at former manufactured gas plant sites.

■ *For more information, contact Ishwar Murarka, (415) 855-2150.*

Remote PV Water Pumping Confirmed as Cost-effective Utility Service

Over 250 water-pumping systems powered by photovoltaic (PV) systems have been installed by ranchers, farmers, homeowners, and private organizations in western and midwestern states in the past five years. To quantify the performance and cost-effectiveness of such systems, EPRI and Sandia National Laboratories have coordinated a demonstration program with 15 utilities and their customers.

During the past two years, the participating utilities have installed PV-powered water-pumping systems at 16 sites. Over two-thirds of the installations involve water supply for grazing cattle, but there are several less usual applications too: systems for pumping well water for a Navajo community in New Mexico, supplying well water to wildlife in Arizona, removing water from a Minnesota landfill, and pumping geothermally heated water used by a fish farm. The systems typically are rated at a few hundred watts each. In some cases, PV panels are pole-mounted near a well, while other systems feature rack mounts on converted windmill structures. The average water output for the installations is about 1700 gallons per day. Output ranges from as low as 900 gallons per day for wildlife watering to as high as 3500 gallons for livestock.

The project has documented that PV water-pumping systems are very cost-effective compared with the conventional utility practice of serving such small loads by extending a distribution line. Savings for the participating utilities were as high as $31,000 and averaged $11,000 per site; the average installed PV pumping system cost was about $6900. Researchers are also tracking the first-year performance of most of the systems and are reporting few problems. A report on first-year performance will be issued by Sandia.

"PV technology applied to water pumping for livestock watering and other uses gives electric utilities an opportunity to provide cost-effective electric service to both utility- and customer-owned loads that up to now have been uneconomical to serve—or simply could not be served," says John Bigger, manager for photovoltaic systems at EPRI. "The results of this project to document benefits and of other efforts by EPRI, Sandia's PV Design Assistance Center, and the Western Area Power Administration will help speed the adoption of this solar technology by utilities for small remote loads."

An IEEE technical paper that provides more details on the project is available; an EPRI technical report is being prepared.

■ *For more information, contact John Bigger, (415) 855-2178.*

New Contracts

Customer Systems

Project	Funding/ Duration	Contractor/EPRI Project Manager
Utility and Customer Power Line Communications (RP2568-32)	$199,400 21 months	Tennessee Center for Research & Development/ *L. Carmichael*
Utility Communications Architecture Technical Coordination (RP2568-34)	$189,600 21 months	Tennessee Center for Research & Development/ *L. Carmichael*
Industrial Customer Segmentation Study (RP2893-11)	$104,500 11 months	RCG/Hagler, Bailly/ *G. Lopez*
Microminiature Power Quality Monitoring Technology (RP2935-25)	$97,200 9 months	TRW/*M. Samotyj*
Laboratory Testing of Prototype Superefficient Refrigerators (RP3188-9)	$125,400 4 months	ETL Testing Laboratories/ *T. Statt*
Demand-Side Management Tracking Systems Development Study (RP3269-24)	$138,200 4 months	Charles River Associates/ *P. Hummel*
Design and Development of Advanced Diffusers for Cold-Air Distribution (RP3280-41)	$171,600 25 months	Colorado State University/ *R. Wendland*
Design and Manufacture of a Prototype Parking/Commercial Facility EV Charging Station, Phase 1 (RP3304-15)	$100,000 8 months	GVO/*G. Purcell*
Energy and Economic Impacts of OHMIC Food Processing Systems (RP3324-7)	$93,000 24 months	Advanced Food Sciences/ *A. Amarnath*
Evaluation for the Seattle City Light Peak Energy Program (RP3337-5)	$176,600 22 months	Quantum Consulting/ *G. Heffner*
Improved Transmission and Distribution Forecasting Methods (RP3337-7)	$83,300 22 months	AUS Consultants/ *G. Heffner*
Application of Industrial Demand-Side Management to Least-Cost T&D System Planning and Operation (RP3337-8)	$110,000 20 months	Resource Dynamics Corp./*G. Heffner*
Advanced Lighting System Development, Evaluation, Demonstration, and Market Introduction (RP3366-1)	$550,000 24 months	Genlyte Group/*K. Johnson*
Alternative Refrigerants Evaluation Program: Condenser-Inside-Tube Heat Transfer Studies (RP3412-51)	$130,600 7 months	University of Illinois, Urbana-Champaign/ *S. Kondepudi*
Measurement of Evaporative Heat Transfer Coefficients of Refrigerant Mixtures R32-R134a and R32-R125-R134a (RP3412-54)	$150,000 24 months	National Institute of Standards and Technology/*T. Statt*
Production and Testing of Hafnium Carbide Single-Crystal Whiskers as Electric Light Filaments (RP3413-1)	$111,100 18 months	Superkinetics/*K. Johnson*
Testing of a Heat Pump Clothes Dryer (RP3417-4)	$67,100 5 months	Arthur D. Little, Inc./ *J. Kesselring*
Concentration of Indoor Pollutants (CIP) Database (RP3512-13)	$213,700 13 months	Lawrence Berkeley Laboratory/*J. Kesselring*
Residential End-Use Technologies Desk Book (RP3512-17)	$157,800 14 months	Energy International/ *J. Kesselring*
Commercial Refrigeration and Dehumidification Technology Transfer (RP3526-4)	$135,000 9 months	Bevilacqua Knight/ *M. Khattar*
Utility Regulatory and End-Use Business Issues (RP3559-13)	$80,000 8 months	Strategy Integration/ *V. Rabl*
Development of Advanced Lead-Acid Battery (RP3593-2)	$1,000,000 12 months	Electrosource/*R. Swaroop*
Electric Vehicle Development, Phase 3 (RP3612-1)	$6,000,000 40 months	Chrysler Corp./*G. Purcell*
Development of End-Use Emissions Software Database: Transportation Module (RP3625-5)	$58,900 8 months	Science Applications International Corp./ *P. Sioshansi*
Market Shapers Project, Part B (RP3640-1)	$145,100 10 months	National Analysts/ *T. Henneberger*
Use of CLASSIFY-Plus for Strategic Planning of Commercial Energy-Efficiency Programs at Florida Power & Light Co. (RP3686-1)	$385,700 11 months	National Analysts/ *T. Henneberger*
Market Shapers Project, Part A (RP4001-11)	$299,900 10 months	National Analysts/ *T. Henneberger*

Electrical Systems

Project	Funding/ Duration	Contractor/EPRI Project Manager
Study of System Operating Impacts of FACTS Technologies (RP3022-25)	$247,900 14 months	ECC/*A. Vojdani*
EMF Workstation (RP3335-9)	$169,600 10 months	Enertech Consultants/ *J. Dunlap*
Development of Optically Controlled Distribution System (RP3389-8)	$384,000 38 months	Drexel University/ *A. Sundaram*
Evaluation of Gases Generated by Heating and Burning of Cables (RP7910-22)	$594,700 37 months	Underwriters Laboratories/ *T. Kendrew*
Ground-Penetrating-Radar Motion Compensation Feasibility Tests (RP7910-24)	$50,000 8 months	Mirage Systems/ *T. Kendrew*
Effects of Intense Fluid Pumping on Forced-Cooled Cables (RP7914-3)	$107,300 8 months	Underground Systems/ *J. Shimshock*
High-Temperature Superconducting Cable: Engineering Support (RP7921-3)	$70,600 8 months	Underground Systems/ *D. Von Dollen*

Environment

Project	Funding/ Duration	Contractor/EPRI Project Manager
Development of Coburning Feed Rate Simulator (COFERS) Software (RP2485-30)	$193,300 21 months	Praxis Engineers/*A. Quinn*
Pilot-Scale Study of Organic Contaminated Soils and Sediments (RP2879-28)	$480,000 27 months	Central Maine Power Co./ *I. Murarka*
Non-Magnetic-Field Examination of the Wire Code Paradox (RP2964-22)	$62,700 5 months	Radian Corp./*L. Kheifets*
PISCES Field Chemical Emissions Monitoring at Two Gas-Fired Boilers and Two Gas Turbines (RP3177-12)	$400,000 14 months	Carnot/*B. Toole-O'Neil*
PISCES Field Sampling at the Tennessee Valley Authority's Plant Allen (RP3177-20)	$201,400 9 months	Southern Research Institute/*P. Chu*
Air Toxics Support Work (RP3453-4)	$211,300 11 months	Southern Research Institute/*R. Chang*
Air Toxics Removal in Flue Gas Desulfurization Systems (RP3470-1)	$351,200 10 months	Radian Corp./*D. Owens*
Mercury Methods Validation Testing (RP3471-1)	$121,500 8 months	Radian Corp./*B. Nott*
Mercury Exposure Assessment Methods (RP3508-1)	$79,600 20 months	ICF Kaiser Engineers/ *L. Levin*
Mercury Exposure Modeling (RP3508-2)	$74,500 8 months	ENSR Consulting & Engineering/*L. Levin*
ILWAS Wetlands Project (RP3561-1)	$303,800 48 months	Tennessee Valley Authority/*D. Porcella*
Visibility Assessment for Regional Emission Distributions (RP3592-1)	$65,400 37 months	Battelle Memorial Institute/ *P. Saxena*
Generic Pollution Prevention Plan (RP3610-1)	$409,000 18 months	Radian Corp./*M. McLearn*
Manufactured Gas Plant Remediation Technology Development Efforts at NYSEG, Cortland/Homer Site (RP3642-1)	$301,600 17 months	New York State Electric & Gas Corp./*B. Nott*

Project	Funding/ Duration	Contractor/EPRI Project Manager
Exploratory & Applied Research		
Neural Networks With Internal Structure in the Analysis of Complex Systems (RP8017-2)	$98,100 20 months	University of Maryland/ *A. Wildberger*
New Polymeric Ionic Conduction Materials (RP8019-4)	$150,000 36 months	Pennsylvania State University/*B. Bernstein*
Decision Fusion and Extrapolation for Security Supervisor Control Systems (RP8030-1)	$100,000 29 months	Drexel University/*P. Hirsch*
Decentralized Control for Structural Uncertainties in Power System Applications (RP8030-2)	$100,000 31 months	University of Wisconsin, Madison/*P. Hirsch*
Particle Turbulence Interactions Near Solid Surfaces (RP8034-1)	$215,400 36 months	University of Minnesota/ *J. Maulbetsch*
Iron-Base Superalloys With B2 Structure Precipitates (RP8043-1)	$199,100 22 months	Northwestern University/ *J. Stringer*
Evaluation of Barium Cerium Oxides for High-Temperature Electrochemical Hydrogen Concentration (RP8062-1)	$55,600 12 months	Institute of Gas Technology/*R. Goldstein*
Material Considerations for Heat Recovery Steam Generators in Gas Turbine Combined-Cycle Plants (RP9000-24)	$57,500 5 months	Fern Engineering/ *B. Dooley*
Assessment of Need for Wetted-Cable Life Estimation (RP9001-3)	$63,700 6 months	Ogden Environmental & Energy Services/ *R. Viswanathan*
Generation & Storage		
Infrared Inspection Technical Evaluation Project (RP2817-31)	$99,600 9 months	Begari/*R. Colsher*
Operating Practices Guidebook: Gas Turbine and Combined-Cycle Power Plant (RP2831-12)	$345,700 33 months	Strategic Power Systems/ *R. Frischmuth*
Use of Scaling Laws to Examine Hydrodynamics and Heat Transfer of Pressurized Fluidized Beds (RP3378-1)	$289,700 41 months	Massachusetts Institute of Technology/*J. Wheeldon*
Compact Simulator Training Technology at Poletti (RP3384-11)	$919,600 34 months	New York Power Authority/ *R. Fray*
Saturator for CASH (Compressed-Air Storage With Humidification) Cycle, Phase 1 (RP3400-1)	$69,200 6 months	Glitsch/*R. Pollak*
Avian Collision Avoidance System: Feasibility Study (RP3404-6)	$94,800 14 months	University of Pittsburgh/ *E. Davis*
Condenser Tube Protective Coating as an Alternative to Retubing (RP3422-1)	$912,700 31 months	Florida Power Corp./ *J. Tsou*
Enhanced Reliability of Replacement Feedwater Heater (RP3455-2)	$477,000 12 months	Louisiana Power & Light Co./*J. Tsou*
Enhanced Performance and Reliability of Water Intakes (RP3456-1)	$820,300 47 months	University of Iowa/ *J. Tsou*
Diagnostic Procedure for Preventive Maintenance, Improved Operations, and Plant Performance Monitoring (RP3459-1)	$414,500 26 months	Florida Power Corp./ *R. Colsher*
Network Diagnostic System: FIRM (Failure Introspection in Rotating Machinery) (RP3459-2)	$300,000 13 months	Analysis & Technology/ *R. Colsher*
Pumped-Storage Turbine Generator Diagnostic System (RP3483-1)	$382,700 25 months	New York Power Authority/ *R. Colsher*
Control and Automation Projects Technical Support Services (RP3485-9)	$323,100 24 months	Raytheon Engineers & Constructors/*R. Colsher*
Root-Cause Analysis Workstation (RP3485-19)	$149,900 13 months	FPI International/ *R. Colsher*
Application of Fossil Plant Automation Technologies at Roxboro Generating Station (RP3487-12)	$1,257,000 50 months	Carolina Power & Light Co./*R. Colsher*

Project	Funding/ Duration	Contractor/EPRI Project Manager
Wind Turbine Technology Development (RP3492-1)	$600,000 6 months	U.S. Windpower/*E. DeMeo*
High-Band-Gap Amorphous Silicon Intrinsic Alloys (RP3505-1)	$250,200 12 months	Solarex Corp./*T. Peterson*
Creep-FatiguePro Software Development (RP3548-2)	$195,000 19 months	Structural Integrity Associates/*G. Pflasterer*
Support for Utility Expansion and Dispatching Studies of IGCASH/ CASHING Power Plants (RP3583-5)	$149,600 7 months	Energy Storage & Power Consultants/*A. Cohn*
Manufactured Gas Plant Remediation Technology Development Efforts at NYSEG, Johnson City (RP3649-1)	$298,400 17 months	New York State Electric & Gas Corp./*S. Yunker*
Integrated Energy Systems		
Investment Strategies: Market Value of Strategic Options (RP1920-8)	$95,700 8 months	Applied Decision Analysis/ *J. Bloom*
Integrated Assessment of Climate Change (RP3441-14)	$250,000 12 months	Carnegie Mellon University/ *L. Williams*
POWERCOACH Case Study for the Tennessee Valley Authority (RP7145-8)	$127,500 4 months	Strategic Decisions Group/ *R. Siddiqi*
MIDAS Model Enhancements (RP7317-1)	$430,000 25 months	M. S. Gerber & Associates/ *L. Rubin*
Nuclear Power		
Life-Cycle Management Technology Transfer From Calvert Cliffs Nuclear Plant (RP2643-35)	$297,600 21 months	Grove Engineering/ *M. Lapides*
Dissimilar Instruments for Calibration Reduction (RP2906-5)	$54,200 8 months	ABB Systems Control Co./ *R. Colley*
Comprehensive, Low-Cost Reliability-Centered Maintenance (RP2970-10)	$636,100 48 months	Erin Engineering & Research/*D. Worledge*
Wrong Unit/Train/Component Error Research, Phase 1 (RP3111-8)	$85,200 8 months	RCG/Hagler, Bailly/ *J. Ketchel*
Bar Coding Applications in Nuclear Power Plants, Phase 1 (RP3111-36)	$281,900 13 months	Encore Technical Resources/*J. Ketchel*
Evaluation of Practicality and Effectiveness of ASME Code Requirements (RP3147-3)	$199,700 15 months	Science Applications International Corp./ *J. Spanner*
Thermal Stratification in Piping Resulting From Convective Currents (RP3153-3)	$50,000 9 months	ABB Combustion Engineering/*J. Kim*
Decision Analysis for Decommissioning (RP3171-4)	$140,200 10 months	Decision Focus/*C. Wood*
Guidelines for Optimizing the Engineering Change Process for Nuclear Power Plants (RP3186-17)	$190,000 9 months	Cygna Energy Services/ *W. Houston*
Guidelines for Using Items Manufactured to Other Industry Standards (RP3186-22)	$72,400 12 months	Sargent & Lundy/*F. Rosch*
Advanced Steam Dump Control System Study (RP3208-2)	$182,100 17 months	Westinghouse Electric Corp./*C. Lin*
Integrated Digital Control System Retrofits for Feedwater and Recirculation Flow Controls (RP3208-3)	$80,800 7 months	AECL Technologies/ *S. Bhatt*
Repair Guidelines for Alloy 600 Penetrations (RP3223-6)	$99,600 12 months	J. A. Jones Applied Research Co./*W. Childs*
Implementation of Piping and Support Operability Criteria (RP3395-1)	$118,800 8 months	ABB Impell Corp./*H. Tang*
Calvert Cliffs Instrumentation and Control Upgrade (RP3414-4)	$100,900 9 months	ABB Combustion Engineering/*C. Wilkinson*
Evaluation of Depleted Zinc Oxide (RP3419-1)	$1,355,900 24 months	General Electric Co./ *C. Wood*

New Technical Reports

Requests for copies of reports should be directed to the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, California 94523; (510) 934-4212. There is no charge for reports requested by EPRI member utilities. Reports will be provided to others in the United States for the price listed or, in some cases, under the terms of a license agreement. Those outside the United States should contact the Distribution Center for price information.

CUSTOMER SYSTEMS

CFCs and Electric Chillers: Selection of Large-Capacity Water Chillers in the 1990s (Revision 1)
TR-100537 (Rev. 1) Final Report (RP2891-78), $200
Contractor: Gilbert & Associates
EPRI Project Manager: M. Blatt

Advanced Lighting Guidelines: 1993 (Revision 1)
TR-101022 (Rev. 1) Final Report (RP2285-26), $200
Contractor: Eley Associates
EPRI Project Manager: K. Johnson

Proceedings: High-Speed Rail and Maglev Workshop
TR-101700 Proceedings (RP3025-2), $200
Contractor: Bevilacqua Knight, Inc.
EPRI Project Manager: E. Riddell

Water-Loop Heat Pump Systems Controls Guide
TR-101863 Final Report (RP2480-18), $200
Contractor: James J. Hirsch & Associates
EPRI Project Manager: M. Khattar

Probabilistic Methods in Forecasting Hourly Loads
TR-101902 Final Report (RP2919-4); $200
Contractor: Quantitative Economic Research, Inc.
EPRI Project Manager: P. Hummel

Minutes of Utility Workshop on Integrating Demand-Side Management (DSM) Into Transmission and Distribution (T&D) Planning
TR-101905 Final Report (RP3337); $200
Contractor: Pacific Gas and Electric Co.
EPRI Project Manager: G. Heffner

Utility End-Use Metering: Methods and Applications—Monograph 1, Electric Utility End-Use Load Research Series
TR-101941 Final Report (RP2980-6); $200
Contractor: SBW Consulting, Inc.
EPRI Project Manager: R. Gillman

Assessment of Active Power Line Conditioning Technologies
TR-102026 Final Report (RP2918-15), $200
Contractor: Electrotek Concepts, Inc.
EPRI Project Manager: B. Banerjee

1992 Survey of Utility Demand-Side Management Programs, Vols. 1 and 2
TR-102193 Final Report (RP2884-2); Vols. 1 and 2, $200 for set
Contractors: Plexus Research, Inc.; Scientific Communications, Inc.
EPRI Project Manager: P. Meagher

EPRI Urban Initiative 1992 Workshop Proceedings: The EPRI Community Initiative
TR-102394 Final Report (RP2788-61), Part 1 (Proceedings), $200; Part 2 (Executive Summary), $50; Part 3 (Presentation Materials), $50
Contractor: Barakat & Chamberlin, Inc.
EPRI Project Managers: S. Baruch, M. Mastroianni

ELECTRICAL SYSTEMS

Database Access Integration Services (DAIS), Vols. 1 and 2
TR-101706 Final Report (RP2949-5); Vols. 1 and 2, $200 each volume
Contractors: Honeywell; Northern States Power Co.
EPRI Project Manager: W. Malcolm

Proceedings: EPRI/NSF Workshop on Application of Advanced Mathematics to Power Systems
TR-101795 Proceedings (RP8010-27), $200
Contractors: ABB Systems Control Co., Inc.; University of Wisconsin, Madison; OR/AICON International
EPRI Project Manager: R. Adapa

Evaluation of a Thyristor-Controlled Phase Angle Regulator Application in the Minnesota Power Transmission System
TR-101932 Final Report (RP3022-13), $200
Contractor: Minnesota Power
EPRI Project Manager: D. Maratukulam

FACTS Device Benefit Assessment Studies on Commonwealth Edison's Power System, Vol. 1: Study of Methods for Improving Stability Margin at the Byron Station
TR-101933 Final Report (RP3022-12, -17), Vol. 1, $200
Contractor: Ontario Hydro
EPRI Project Manager: D. Maratukulam

FACTS Device Benefit Assessment Studies on Commonwealth Edison's Power System, Vol. 2: Study of STATCON Use to Improve Voltage Stability and Power Quality at Schaumburg Substation
TR-101933 Final Report (RP3022-2, -17); Vol. 2, $200
Contractor: General Electric Co.
EPRI Project Manager: D. Maratukulam

Removal of PCBs From Oils by Solvent Extraction
TR-101979 Final Report (RP2028-14); $200
Contractor: Veridyne, Inc.
EPRI Project Manager: G. Addis

Transmission Cable Magnetic Field Management
TR-102003 Final Report (RP7898-37); $500
Contractor: Power Technologies, Inc.
EPRI Project Manager: J. Shimshock

Extended Transient–Midterm Stability Program Version 3.0, Vols. 1–6
TR-102004 Final Report (RP1208-9); Vol. 1, $200; Vols. 2–6, license required
Contractor: Ontario Hydro
EPRI Project Managers: P. Hirsch, M. Lauby

WEMOS™ Gas-in-Oil Monitor
TR-102005 Final Report (RP2445-1); $200
Contractor: ABB Transmission Technology Institute
EPRI Project Manager: G. Addis

Electromagnetic Transients in Substations, Vols. 1–5
TR-102006 Final Report (RP2674-1); Vols. 1–5, $200 each volume
Contractor: BDM International, Inc.
EPRI Project Managers: S. Wright, F. Phillips, S. Nilsson

Proceedings: Bulk Transmission Loss Evaluation and Identification Workshop
TR-102159 Proceedings (RP2473-54); $200
Contractor: Decision Systems International
EPRI Project Manager: D. Maratukulam

Proceedings: EPRI/NERC Forum on Voltage Stability
TR-102222 Proceedings (RP2473-62), $200
Contractor: Thomas Kennedy
EPRI Project Manager: D. Maratukulam

Dynamic Reduction Version 1.0, Vols. 1–4
TR-102234 Final Report (RP2447-1); Vol. 1, $200; Vols. 2–4, license required
Contractor: Ontario Hydro
EPRI Project Manager: P. Hirsch

Harmonics and Instabilities in Switching Circuits
TR-102317 Final Report (RP4000-29, RP8010-33); $200
Contractor: University of Wisconsin, Madison
EPRI Project Manager: A. Edris

Helicopter-Based Live-Line Work, Vol. 1: Helicopter Platform Work Between Phases
TR-102318 Final Report (RP2472-6); Vol. 1, $200
EPRI Project Manager: J. Hall

Helicopter-Based Live-Line Work, Vol. 2: Bosun's Chair Work Near Suspension Insulators
TR-102318 Final Report (RP2472-6); Vol. 2, $200
EPRI Project Manager: J. Hall

Field Measurement of Cable Dissipation Factor
TR-102449 Final Report (RP7910-5); $1000
Contractor: Power Technologies, Inc.
EPRI Project Manager: T. Rodenbaugh

Workshop Proceedings: Advanced Diagnostics for Substation Equipment
TR-102450 Proceedings (RP2747); $200
EPRI Project Manager: J. Porter

ENVIRONMENT

Proceedings: EPRI Workshop on NO_x Controls for Utility Boilers
TR-101719 Proceedings (RP2916); $300
EPRI Project Manager: A. Kokkinos

The Response of Plants to Interacting Stresses: PGSM Version 1.3 Model Documentation
TR-101880 Final Report (RP2799-6); $200
Contractor: Systech Engineering, Inc.
EPRI Project Manager: R. Goldstein

Chemical and Physical Characteristics of Tar Samples From Selected Manufactured Gas Plant (MGP) Sites
TR-102184 Final Report (RP2879-12); $200
Contractors: Atlantic Environmental Services, Inc.; META Environmental, Inc.
EPRI Project Managers: I. Murarka, L. Goldstein

GENERATION & STORAGE

Corrosion Fatigue Boiler Tube Failures in Waterwalls and Economizers, Vol. 3: Field Testing and Stress Analysis
TR-100455 Final Report (RP1890-5); Vol. 3, $200
Contractors: Ontario Hydro; Babcock & Wilcox Co.
EPRI Project Manager: B. Dooley

Interface for Consolidated Edison's Waterside Station Compact Simulator: PC-TRAX to Westinghouse Distributed Processing Family, Vols. 1 and 2
TR-101790 Final Report (RP3152-2); Vols. 1 and 2, $200 each volume
Contractor: Science Applications International Corp.
EPRI Project Manager: R. Fray

Materials Support for EPRI Fluidized-Bed Combustion Program, Vols. 1 and 2
TR-101804 Final Report (RP979-20); Vol. 1, $200; Vol. 2, forthcoming
Contractor: Battelle, Columbus Division
EPRI Project Manager: B. Dooley

Proceedings of the Steam and Combustion Turbine-Blading Conference and Workshop, 1992
TR-102061 Proceedings (RP1856-9); $200
Contractor: Stress Technology, Inc.
EPRI Project Manager: T. McCloskey

Feedpump Operation and Design Guidelines, Summary Report
TR-102102 Final Report (RP1884-10); $200
Contractor: Sulzer Brothers, Ltd.
EPRI Project Manager: T. McCloskey

Development of Corrosion-Resistant Alloy for Coal Gasification Plants
TR-102255 Final Report (RP2048-10); $200
Contractors: IHI; Sumitomo Metals Co.
EPRI Project Manager: W. Bakker

Proceedings: 1992 Fuel Oil Utilization Workshop
TR-102263 Proceedings (RP2778-8); $200
Contractor: Carnot
EPRI Project Manager: W. Rovesti

Proceedings: Effects of Coal Quality on Power Plants—Third International Conference
TR-102280 Proceedings (RP2256-8); $200
Contractor: Reaction Engineering International
EPRI Project Manager: A. Mehta

The Market for Solar Photovoltaic (PV) Technology
TR-102290 Final Report (RPOCBD-1); $1200
Contractor: Arthur D. Little, Inc.
EPRI Project Manager: K. Vejtasa

Proceedings: 1992 Workshop on Optical Sensing in Utility Applications
TR-102349 Proceedings (RP2487); $200
EPRI Project Manager: J. Stein

Practical Aspects of On-Load Generator Testing
TR-102351 Final Report (RP2328-2); $200
Contractor: Ontario Hydro Research Division
EPRI Project Manager: J. Stein

Improved Radio-Frequency Monitoring for Turbine Generators, Vols. 1 and 2
TR-102352 Final Report (RP2591); Vol. 1, $200; Vol. 2, license required
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: J. Stein

Guidelines for Chemical Cleaning of Fossil-Fueled Steam-Generating Equipment
TR-102401 Final Report (RP2712-6); $200
Contractor: Sheppard T. Powell Associates
EPRI Project Manager: B. Dooley

Proceedings: 1992 EPRI Gas Turbine Procurement Seminar
TR-102483 Proceedings (RP2915-6); $200
Contractor: Carnot
EPRI Project Manager: H. Schreiber

Proceedings: Advanced Physical Coal Cleaning—A State-of-the-Art Review
TR-102635 Proceedings (RP2704-5); $200
Contractor: CQ Inc.
EPRI Project Manager: R. Wolk

NUCLEAR POWER

Technical Repair Guidelines for Limitorque Models SMB 0 Through 4 Valve Actuators
NP-7214 Final Report (RP2814-68); $30,000
Contractor: PowerSafety International
EPRI Project Manager: V. Varma

Evaluation of Leak and Burst Characteristics of Roll Transitions Containing Primary Water Stress Corrosion Cracks
NP-7474 Final Report (RPS406-7); $1000
Contractor: Westinghouse Science and Technology Center
EPRI Project Manager: A. McIlree

Guideline for the Seismic Technical Evaluation of Replacement Items for Nuclear Power Plants
NP-7484 Final Report (RPQ101-29); $200
Contractors: EQE International; Programmatic Solutions; System 1, Inc.
EPRI Project Managers: T. Mulford, W. Houston

Proceedings: EPRI Power Plant Valves, Symposium 4
TR-101859 Application Report (RP3232-1); call for price
EPRI Project Managers: J. Lance, J. Hosler, J. Tsou

Assessment of the Effective Dose Equivalent for External Photon Radiation, Vol. 1: Calculational Results for Beam and Point Source Geometries
TR-101909 Final Report (RP3099-10); Vol. 1, $200
Contractor: Texas A&M University
EPRI Project Manager: C. Hornibrook

Proceedings: EPRI Computer-Assisted Technologies for NDE and Plant Maintenance
TR-101910 Proceedings (RP3148-2); $500
Contractor: EPRI Nondestructive Evaluation Center
EPRI Project Managers: S. Liu, M. Avioli

Radiation Hardening of CMOS-Based Circuitry in SMART Transmitters, Phase 1: Feasibility
TR-101915 Final Report (RP2614-58); $200
Contractor: Sandia National Laboratories
EPRI Project Managers: J. Weiss, R. Shankar

Evaluation of Containment Hydrogen and Oxygen Analyzers
TR-101916 Final Report (RP2409-16); $200
Contractor: Mollerus Engineering Corp.
EPRI Project Managers: R. Shankar, J. Weiss

RADSOURCE, Vol. 1, Parts 1 and 2
TR-101960 Final Report (RP2412-19); Vol. 1, Parts 1 and 2, $200 each part
Contractor: Vance & Associates, Inc.
EPRI Project Manager: C. Hornibrook

Browns Ferry Instrumentation and Control Upgrade Methodology
TR-101963 Interim Report (RP3332-1); license required
Contractor: Mollerus Engineering Corp.
EPRI Project Manager: R. Torok

Reliability-Centered Maintenance Workstation User's Guide, Vol. 2
TR-101967 Final Report (RP3134-2); Vol. 2, $50,000
Contractor: Halliburton NUS Environmental Corp.
EPRI Project Manager: R. Colley

Guidelines and Criteria for Nuclear Piping and Support Evaluation and Design, Vols. 1–8
TR-101968 Final Report (RP2967-2, -3); Tier 1, Vol. 1, $200; Tier 2, Vols. 2–8, $500 each volume
Contractors: Duke Power Co.; ABB Impell Corp.
EPRI Project Managers: Y. Tang, H. Tang

Earthquakes and Tectonics Expert Judgment Elicitation Project
TR-102000 Final Report (RP3055-13); $200
Contractor: Geomatrix Consultants, Inc.
EPRI Project Manager: R. Shaw

Evaluation of Transportability of the VSC Basket
TR-102001 Final Report (RP3290-1); $200
Contractor: Sierra Nuclear Corp.
EPRI Project Manager: R. Lambert

Utility Maintenance, Inspection, and Training Facility Sourcebook, Vols. 1 and 2
TR-102028 Application Report (RP3232-1); Vols. 1 and 2, $2000 each volume
Contractors: NDX International; MSD Engineering, Inc.
EPRI Project Manager: K. Huffman

Seismic and Dynamic Reliability of Eroded/Corroded Piping Components
TR-102066 Final Report (RP3010-1); $1000
Contractor: Anco Engineers, Inc.
EPRI Project Manager: Y. Tang

Use of Nondestructive Evaluation Data to Improve Analysis of Reactor Pressure Vessel Integrity
TR-102074 Application Report (RP3148-2, RP3232-1); call for price
Contractors: Yankee Atomic Electric Co.; EPRI Nondestructive Evaluation Center
EPRI Project Manager: J. Lance

Nondestructive Evaluation (NDE) Training Sourcebook, Vol. 1: Commercially Available Training Courses
TR-102105 Application Report (RP3232-1); Vol. 1, $2000
EPRI Project Manager: J. Lance

Nondestructive Evaluation (NDE) Training Sourcebook, Vol. 2: EPRI NDE Center Training Courses
TR-102105 Application Report (RP3232-1); Vol. 2, $2000
EPRI Project Manager: J. Lance

Survey and Assessment of Conventional Software Verification and Validation Techniques
TR-102106 Final Report (RP3093-1); $200
Contractor: Science Applications International Corp.
EPRI Project Managers: J. Naser, W. Reuland

NEI Parsons, Ltd., Boresonic Inspection System Evaluation
TR-102126 Application Report (RP3232-1); call for price
EPRI Project Manager: J. Lance

PWR Secondary Water Chemistry Guidelines (Revision 3)
TR-102134 (Rev. 3) Final Report (RP2493, RPS401); $200
EPRI Project Manager: C. Wood

BWR Consolidation System Final Design Report
TR-102158 Final Report (RP3100-2); $200
Contractor: B&W Fuel Co.
EPRI Project Manager: R. Lambert

Service Water System Repair Replacement Guidelines
TR-102174 Application Report (RP3232-1); call for price
Contractors: EPRI Nondestructive Evaluation Center; W. E. Newell and Associates, Inc.
EPRI Project Manager: J. Lance

A Probabilistic Approach for Predicting Concrete Containment Leakage
TR-102176 Final Report (RP2172-1); Tier 1, $200; Tier 2, license required
Contractor: Analech Research Corp
EPRI Project Manager: H. Tang

Guidelines for Estimation or Verification of Equipment Natural Frequency
TR-102180 Final Report (RP2925-2); $200
Contractor: Anco Engineers, Inc.
EPRI Project Manager: R. Kassawara

HEPTID: Heat Exchanger Pulled-Tube Image Database
TR-102191 Application Report (RP3232-1); call for price
EPRI Project Manager: J. Lance

Service (Salt) Water System Life-Cycle Management Evaluation
TR-102204 Final Report (RP3343-1); $200
Contractors: Stone and Webster Engineering Corp.; Baltimore Gas & Electric Co.
EPRI Project Manager: M. Lapides

Modification of Alloy Surfaces Using Pulsed Energy: Phase 2
TR-102232 Final Report (RP3500-7); $20,000
Contractor: Failure Analysis Associates
EPRI Project Manager: J. Nelson

Northeast Inspection Services, Inc., Boresonic Inspection System Evaluation
TR-102256 Final Report (RP3232-1); $200
EPRI Project Manager: J. Lance

Pipe Failure Study Update
TR-102266 Final Report (RP3200-6); $20,000
Contractor: Halliburton NUS Environmental Corp.
EPRI Project Managers: J. Sursock, B. Chu

System Specification for the Wireless Programmable Process Monitoring System
TR-102287 Final Report (RP2409-14); $500
Contractor: Battelle Memorial Institute
EPRI Project Managers: R. Shankar, R. James

Measurement of In-Core and Recirculation System Response to Hydrogen Water Chemistry at the Duane Arnold Energy Center
TR-102310 Final Report (RP1930-1); $100,000
Contractor: General Electric Co.
EPRI Project Manager: J. Nelson

Service Water System Inspection Locator (SWSIL)
TR-102311 Interim Report (RP2939-9); $200
Contractor: Structural Integrity Associates
EPRI Project Manager: D. Cubicciotti

BWR/5 Full-System Decontamination Feasibility Study
TR-102332 Final Report (RP1329-3); $200
Contractor: Niagara Technical Consultants
EPRI Project Manager: C. Wood

Residual Stresses in Roller-Expanded Steam Generator Tube Transitions
TR-102355 Final Report (RPS406-11); $200
Contractor: Pennsylvania State University
EPRI Project Manager: A. McIlree

Proceedings: Thirteenth Annual EPRI Nondestructive Evaluation Information Meeting—NDE Research Progress in 1992
TR-102381 Proceedings (RP1570-14); Tier 1, $200; Tier 2, $500
EPRI Project Manager: M. Avioli

Fracture Toughness Characterization of Japanese Reactor Pressure Vessel Steels: Joint EPRI-CRIEPI RPV Embrittlement Studies
TR-102409 Final Report (RP2975-14, -27); $200
Contractors: Materials Engineering Associates, Inc.; ATI Consulting
EPRI Project Manager: T. Griesbach

Comparative System Economics of Concrete Casks for Spent-Fuel Storage
TR-102415 Final Report (RP3073-2); $200
Contractor: Sierra Nuclear Corp.
EPRI Project Manager: R. Lambert

The Effects of Heat Treatment and Environment on Corrosion Fatigue, Vols. 1 and 2
TR-102436 Final Report (RP2181-5); Vols. 1 and 2, $200 each volume
Contractor: Massachusetts Institute of Technology
EPRI Project Manager: J. Nelson

The Effect of Thermal Treatment on the Fracture Properties of Alloy X-750 in Aqueous Environments
TR-102437 Interim Report (RP2181-5); $200
Contractor: Massachusetts Institute of Technology
EPRI Project Manager: J. Nelson

Shipment of Spent Fuel in Storage Canisters
TR-102462 Final Report (RP2717-12); $200
Contractor: Pacific Nuclear Fuel Services, Inc.
EPRI Project Manager: R. Lambert

Proceedings: Electromagnetic Interference Control in Modern Digital Instrumentation and Control Upgrades
TR-102479 Proceedings (RP3604-3); $200
EPRI Project Manager: S. Bhatt

Speciation and Chemical Activities in Superheated Sodium Borate Solutions
TR-102491 Final Report (RPS407-21); $200
Contractor: Sonoma Research Co.
EPRI Project Managers: P. Paine, P. Millett

Impurity Hideout/Hideout Return at the Susquehanna 2 BWR
TR-102520 Topical Report (RP2946-5); $200
Contractor: NWT Corp.
EPRI Project Manager: D. Cubicciotti

Influence of Defect Kind and Size on Margins With Respect to Fast Fracture of Irradiated PWR Vessels: Joint EPRI-CRIEPI RPV Embrittlement Studies
TR-102521 Final Report (RP2975-17); $200
Contractor: Framatome
EPRI Project Manager: T. Griesbach

Eddy-Current Steam Generator Data Analysis Performance
TR-102549 Final Report (RP2705-9, RP3112-1, RPS404-20); $200
Contractor: Anacapa Sciences, Inc.
EPRI Project Managers: J. O'Brien, J. Yasutake, C. Welty, M. Behravesh

Guidance on New DOT Training Requirements for Hazardous Materials Employees
TR-102662 Final Report (RP2691-13); $200
Contractor: Alfred W. Grella
EPRI Project Manager: C. Hornibrook

Proceedings: 1992 EPRI Radwaste Workshop
TR-102663 Proceedings (RP2414-55); $200
Contractor: Mary Kelleher-Forsyth
EPRI Project Manager: C. Hornibrook

New Computer Software

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CEM Database: Continuous Emissions Monitoring Utility and Vendor Databases
Version 2.0 (PC-DOS)
Developer: Engineering Science
EPRI Project Manager: Ruseli Owens

CEM RW™: Continuous Emissions Monitoring Reporting Workstation
Version 1.0 (PC-DOS)
Developer: Electric Software Products
EPRI Project Manager: Ruseli Owens

CG-DAMS™: Concrete Gravity Dam Analysis Modular Software
Version 2.0–4 (PC-DOS)
Developer: Anatech Research Corp.
EPRI Project Manager: Doug Morris

CHIRON: Prediction of Failed Fuel Rods
Version 2.1 (PC-DOS)
Developer: S. Levy, Inc.
EPRI Project Manager: Odelli Ozer

CONDENSER*COR™: Corrosion of Condenser Materials
Version 1.0 (PC-DOS)
Developer: National Institute of Standards and Technology
EPRI Project Managers: Barry Syrett, John Tsou

COOLTA™: Cooling Tower Advisor
Version 2.0 (PC-DOS/Windows)
Developer: Electric Software Products
EPRI Project Manager: John Tsou

DSManager: Demand-Side Management Analysis Software
Version 2.0 (PC-DOS)
Developer: Electric Power Software Center
EPRI Project Manager: Perry Sioshansi

DYNAMICS
Version 2.0 (Sun-UNIX)
Developer: Decision Focus, Inc.
EPRI Project Manager: James Fortune

EMTP Workstation: Electromagnetic Transients Program
Version 1.0 (DEC-ULTRIX; RS6000-AIX; Sun-UNIX)
Developer: Electrotek Concepts, Inc.
EPRI Project Manager: Rambabu Adapa

ESPRE: EPRI Simplified Program for Residential Energy
Version 2.1 (PC-DOS)
Developer: Arthur D. Little, Inc.
EPRI Project Manager: John Kesselring

FGDPRISM™: Flue Gas Desulfurization Process Integration and Simulation Model
Version 2.0 (PC-DOS)
Developer: Radian Corp.
EPRI Project Manager: Robert Moser

HELM-PC: Hourly Electric Load Model
Version 2.0 (PC-DOS/Windows)
Developer: ICF Resources
EPRI Project Manager: Paul Meagher

HOTCALC: Commercial Water Heating Performance Simulation Tool
Version 2.0 (PC-DOS)
Developer: D. W. Abrams & Associates
EPRI Project Manager: Karl Johnson

HWCA™: Hydrogen Water Chemistry Assistant
Version 1.2 (PC-DOS)
Developer: Aptech Engineering Services
EPRI Project Manager: Larry Nelson

MarketTREK™: Market Penetration Forecasting Tool
Version 1.08 (PC-DOS/Windows)
Developer: Research Triangle Institute
EPRI Project Manager: Paul Meagher

MULTEQ-Redox
Version 2.2 (PC386/486-DOS)
Developer: S-Cubed
EPRI Project Manager: Peter Millett

PMOS™: Plant Modification Operating Savings
Version 1.0 (PC-DOS)
Developer: Decision Focus, Inc.
EPRI Project Manager: Dave O'Connor

PMW: Plant Monitoring Workstation
Version 4.1 (DEC-VMS)
Developer: Power Technologies, Inc.
EPRI Project Manager: Dominic Maratukulam

SOAPP™: State-of-the-Art Power Plant
Version 1.0 (PC386-DOS/Windows)
Developer: Sargent & Lundy
EPRI Project Manager: Stan Pace

SQUG Database: Database System of Power Plant Equipment Seismic Experience
Version 0 (CD-ROM)
Developer: EQE International
EPRI Project Manager: Robert Kassawara

TLIM: Transmission Limitation Program
Version 1.0 (Apollo-AEGIS; DEC-ULTRIX; DEC-VMS; IBM-MVS; Prime-PRIMOS; RS6000-AIX; Sun-UNIX)
Developer: Ontario Hydro
EPRI Project Manager: Peter Hirsch

TRELSS: Transmission Reliability Evaluation for Large-Scale Systems
Version 1.2 (IBM-MVS; PC-DOS; Prime-PRIMOS)
Developer: Southern Co. Services
EPRI Project Manager: Rambabu Adapa

UNIRAM: Power Generation System Availability Assessment Model
Version 4.0 (PC386/486-DOS)
Developer: ARINC Research Corp.
EPRI Project Manager: Vito Longo

EPRI Events

NOVEMBER

3–4
Duke Power–EPRI Power Quality Conference
Charlotte, North Carolina
Contact: Carrie Koeturius, (510) 525-1205

3–5
National Commercial Cool Storage Conference
Houston, Texas
Contact: Lise Smolak, (614) 846-7338

5
Municipal Water and Wastewater Conference
Seattle, Washington
Contact: Keith Carns, (510) 262-9506

7–12
International Conference on Photochemical Measurement and Modeling Studies
San Diego, California
Contact: Pam McCalla, (412) 232-3444

8–11
4th Annual Seminar on Decision Analysis for Utility Planning
San Diego, California
Contact: Katarina Rolfes, (415) 854-7101

9
Low-Level-Waste Training Courses
Monterey, California
Contact: Linda Nelson, (415) 855-2127

10–12
International Low-Level-Waste Conference
Monterey, California
Contact: Linda Nelson, (415) 855-2127

16–18
International Conference on Fossil Plant Simulators, Modeling, and Training
New Orleans, Louisiana
Contact: Susan Bisetti, (415) 855-7919

16–19
1993 Power Quality Applications/ Power Electronics Conference and Exhibit
San Diego, California
Contact: Carrie Koeturius, (510) 525-1205

19
2d International Seminar on Subchannel Analysis
Palo Alto, California
Contact: Lance Agee, (415) 855-2106

22–23
Lightning Protection Design Workstation Workshop
Washington, D.C.
Contact: Ralph Bernstein, (415) 855-2023

30–December 3
Transformer Performance, Monitoring, and Diagnostics
Palo Alto, California
Contact: John Niemkiewicz, (215) 595-8871

DECEMBER

1–3
2d National Electric Vehicle Infrastructure Conference
Scottsdale, Arizona
Contact: Pam Turner, (415) 855-2010

6
Air Toxics R&D Results
Cleveland, Ohio
Contact: Denise O'Toole, (415) 855-2259

6–9
4th International Conference on Cold Fusion
Maui, Hawaii
Contact: Linda Nelson, (415) 855-2127

7
Air Toxics R&D Results
Atlanta, Georgia
Contact: Denise O'Toole, (415) 855-2259

7
Clean Air Response: Achieving Compliance in an Evolving Market
Location to be announced
Contact: Susan Marsland, (415) 855-2946

7–9
Utility Motor and Generator Predictive Maintenance Workshop
San Francisco, California
Contact: Susan Bisetti, (415) 855-7919

8
Air Toxics R&D Results
Denver, Colorado
Contact: Denise O'Toole, (415) 855-2259

8–9
6th Annual Conference on Utility Strategic Asset Management
St. Petersburg, Florida
Contact: Lori Adams, (415) 855-8763

8–10
Efficient Lighting Symposium
Scottsdale, Arizona
Contact: David Ross, (703) 742-8402

8–10
Expert Systems Applications for the Electric Power Industry
Phoenix, Arizona
Contact: Jouni Keronen, (415) 855-2020

JANUARY 1994

18–20
Fossil Plant Inspections
San Antonio, Texas
Contact: Lori Adams, (415) 855-8763

25
Electric Arc Furnace Dust Treatment Symposium
Pittsburgh, Pennsylvania
Contact: John Kollar, (412) 268-3243

25
EPRI Partnership for Industrial Competitiveness
Pittsburgh, Pennsylvania
Contact: Jamil Nehme, (916) 497-1452

FEBRUARY

7–8
Workshop on Rate Design in the 1990s
Tampa, Florida
Contact: Pam Turner, (415) 855-2010

9–11
Innovative Electricity Pricing Conference
Tampa, Florida
Contact: Pam Turner, (415) 855-2010

MARCH

14–16
Asbestos Control
San Diego, California
Contact: Linda Nelson, (415) 855-2127

14–16
EMF Science and Communication Seminar
Santa Clara, California
Contact: Amelia Birney, (612) 623-4600

23–25
Fossil Plant Cycling
New Orleans, Louisiana
Contact: Lori Adams, (415) 855-8763

23–25
Weld and Repair Technology for Fossil Power Plants
Williamsburg, Virginia
Contact: Susan Bisetti, (415) 855-7919

MAY

3–5
Heat Rate Improvement
Baltimore, Maryland
Contact: Susan Bisetti, (415) 855-7919

11–13
NO_x Controls for Utility Boilers
Scottsdale, Arizona
Contact: Pam Turner, (415) 855-2010

17–19
Fluidized-Bed Combustion for Power Generation
Atlanta, Georgia
Contact: Linda Nelson, (415) 855-2127

17–19
6th Predictive Maintenance Conference
Philadelphia, Pennsylvania
Contact: Lori Adams, (415) 855-8763

19–20
Improving Building Systems in Hot and Humid Climates
Arlington, Texas
Contact: Susan Swanson, (409) 862-2291

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ELECTRIC POWER RESEARCH INSTITUTE
Post Office Box 10412, Palo Alto, California 94303

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