Biodiversity

Also in this issue • Water Regulations • Component Life • Solid-Oxide Fuel Cells

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Cover: Diverse and healthy ecosystems are a foundation for everything we do, providing us with food, clean air and water, and the resources from which we derive such benefits as life-saving medicines. Utilities are beginning to integrate biodiversity issues into their broader environmental programs.

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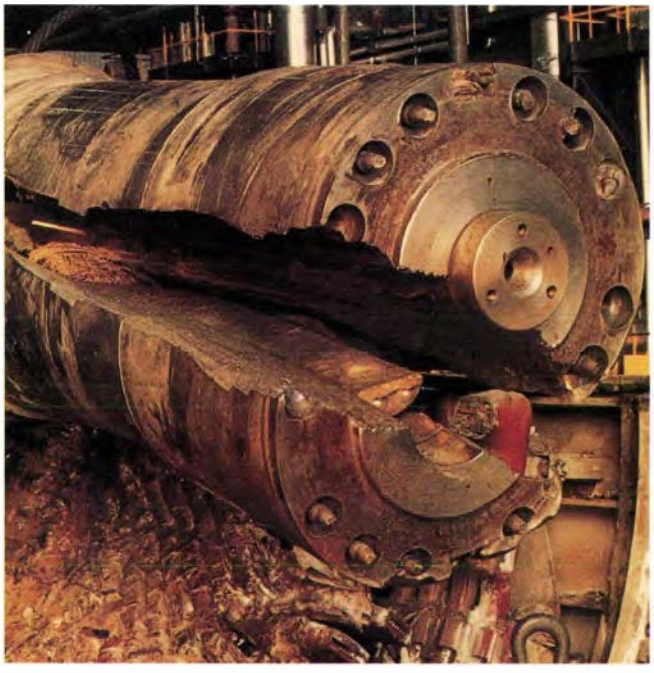

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NCC Device

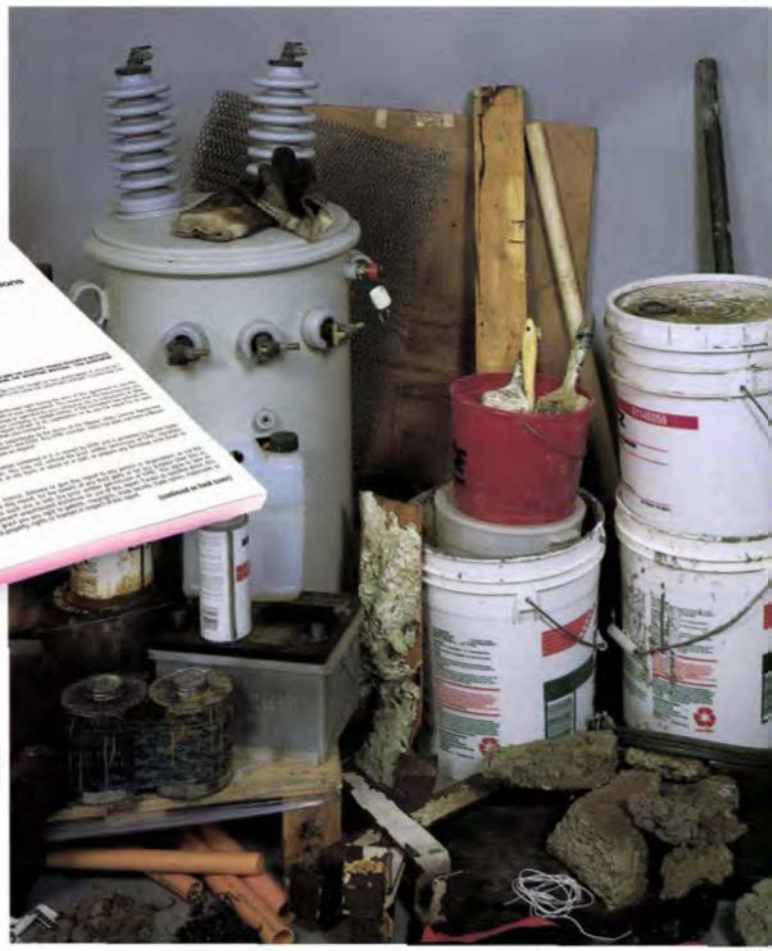
EPRI research indicates that a significant source of residential magnetic fields is ground currents—currents from a home's electrical grounding system that can wind up on its water piping system and travel to nearby homes via the municipal water supply line. EPRI has developed a device that virtually eliminates these stray, or "net," currents and the magnetic fields they generate. Called the net current control (NCC) device, this tool is installed along the service drop to a customer's house to redirect the flow of current, encouraging it to return to the distribution system through the home's service line rather than through water pipes. The NCC device also reduces stray currents coming from neighboring homes or other sources. Unlike other techniques for reducing ground currents, the NCC device does not interfere with the safety and effectiveness of a home's grounding system.

For more information, contact Leeka Kheifets, (415) 855-8976. To order, call David Fugate at Electric Research and Management, (412) 826-3222.

Pollution Prevention Report

Voluntary pollution prevention programs not only minimize the production of noncombustion wastes from power plant auxiliary operations but can also reduce disposal costs, avoid future liability, and keep electric utilities one step ahead of environmental regulations. This report (TR-104111) details a six-step process EPRI has developed for pollution prevention programs—a process consistent with total quality environmental management—and highlights case studies of successful utility programs that followed the process. Included in the report are lessons learned from the case studies, which involved such wastes as used antifreeze, oily shop towels, and empty containers.

For more information, contact Mary McLearn, (415) 855-2487. To order, call the EPRI Distribution Center, (510) 934-4212.



UFIM

Maintaining a low-cost inventory of power plant fuel without creating an excessive risk of depleting supplies is the key to skillful fuel inventory management. The Utility Fuel Inventory Model (UFIM) was developed to help electric utilities with coal-fired power plants achieve this optimal balance. Version 3.11 of UFIM uses analytical techniques to account for the types of fuel inventory problems commonly faced by utilities, such as disruptions in fuel supply delivery, unexpected variations in fuel burn, and seasonal impacts on coal supply. The model also helps decision makers use plant dispatch policy as a means of controlling fuel inventory during shortage periods.

For more information, contact Susan Marsland, (415) 855-2946. To order, call the Electric Power Software Center, (800) 763-3772.

NO_x Tuning Guide

Federal and state regulations require electric utilities to reduce emissions of nitrogen oxides (NO_x) from their coal-fired power plants. This guide (TR-105109) lays out sequential procedures that enable utility managers and engineers to plan and conduct NO_x emissions testing programs for these plants, to evaluate and interpret the resulting data, and to design NO_x reduction programs using combustion tuning. The combustion-tuning strategy can reduce NO_x emissions by 10–30% while optimizing boiler operation and improving heat rate. For boilers only marginally above NO_x emissions limits, this strategy may eliminate the need for low-NO_x hardware retrofits, saving $10–$20/kW. Even power plants that must retrofit low-NO_x burners to achieve reductions can cut costs through combustion tuning.

For more information, contact Jeff Stallings, (415) 855-2427. To order, call the EPRI Distribution Center, (510) 934-4212.

Low-Cost Radio

Many electric utilities recognize the benefits of distribution automation technology, which automatically alerts utilities to outages and other disturbances on the electrical distribution system. However, the high cost of this technology has prevented many power companies from deploying it. Now there is a low-cost radio available that substantially reduces the capital costs of implementing distribution automation systems.

Developed jointly by EPRI, Southern California Edison, and Metricom, the spread spectrum packet radio is a modified version of an earlier Metricom radio and sells for about half the cost of the original. The radio is specifically designed for distribution automation and remote meter reading applications.

For more information, contact Ashok Sundaram at EPRI, (415) 855-2304, or Bob Yinger at SCE, (818) 812-7336. To order, call Dennis Perrone at Metricom, (408) 399-8216.

Global Climate Change: Sunspots Revisited

For nearly two centuries, scientists have speculated about the possible effect of sunspots on global climate, but the mechanism that might be involved has remained a matter of considerable controversy. A central question is how total solar irradiance—the amount of energy received by the earth from the sun—is affected by sunspot activity, which follows an 11-year cycle.

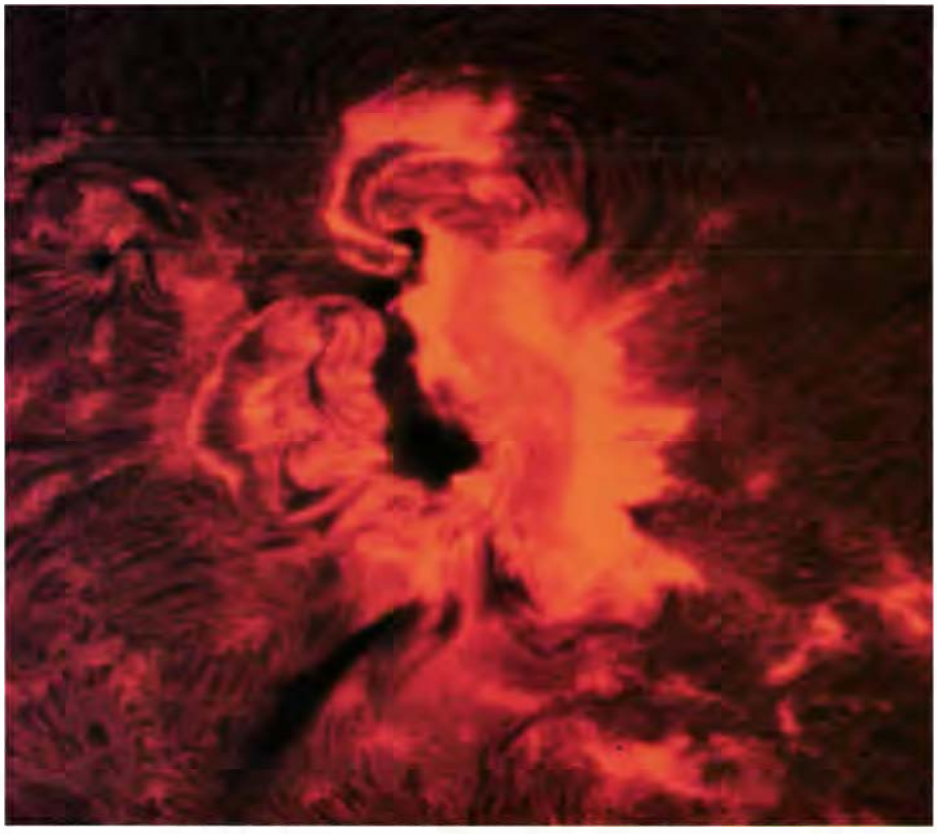
It has been commonly assumed that total solar irradiance would decrease as the number of dark sunspots increased. Direct satellite measurements of irradiance, however, have shown just the opposite to be the case. This means that given more sunspots, more energy is delivered to the atmosphere and global temperatures should rise. Building on this new understanding, recent research, sponsored in part by EPRI, indicates that looking at the combined effects of changes in solar irradiance and increases in atmospheric greenhouse gases offers the best explanation yet for the observed rise in average global temperature over the last century.

According to current theory, sunspots occur in pairs as magnetic disturbances in the convective plasma near the sun's surface. Magnetic field lines emerge from one sunspot and reenter at the other spot. During periods of increased magnetic activity, the sun is brighter and more charged particles are emitted from the solar surface.

Not only does the increased brightness of the sun tend to warm the earth, but also the solar wind shields the atmosphere from cosmic rays, which produce carbon 14. Because of this effect, measuring carbon 14 in tree rings offers a way of inferring the sun's magnetic history. Studies of changes in both the magnetic field coverage and the brightness of nearby stars have also provided a better understanding of the connection between the sun's magnetism and changes in its irradiance.

Using this information and a global climate model based on energy conservation, Sallie Baliunas and Willie Soon of the Harvard-Smithsonian Center for Astrophysics and Eric Posmentier of Long Island University constructed a profile of atmospheric climate "forcing" due to combined changes in solar irradiance and emissions of greenhouse gases between 1880 and 1993. They found that the temperature variations predicted by their model accounted for up to 92% of the temperature changes actually observed over the period—by far the closest match yet achieved. Their results also suggest that the sensitivity of climate to the effects of solar irradiance is about 27% higher than its sensitivity to forcing by greenhouse gases.

An intriguing sidelight to this discovery is the implication that, at times, the sun's influence on climate may be dramatically greater. Studies of the sun and other stars show that they spend about a quarter of their time in a magnetically quiescent state with very few sunspots. The last such event on our sun occurred in the late seventeenth century and was associated with an extended period of unusually cold temperatures known as the Little Ice Age. No one has yet found a way to predict when such an episode might recur.



Sunspots mark changes in the sun's magnetic activity.

■ *For more information, contact John Maulbetsch, (415) 855-2438.*

Genetic Engineering Holds Promise for Affordable Biomass

In recent years, genetic engineering has been used to produce tastier tomatoes, virus-resistant squash, and cotton plants that can kill insects. Now, with support from EPRI and others, this relatively new realm of science could also help make biomass—in the form of poplar trees—an affordable power plant fuel.

Funded by EPRI, the U.S. Department of Energy, and a number of pulp and paper companies, researchers at Oregon State University are genetically engineering poplar trees to increase yields and reduce the costs associated with biomass production. Energy crops generally cost between $2 and $3.50 per million Btu, compared with less than $2 per million Btu for natural gas and about $1 per million Btu for coal. "For electric utilities facing increased competition, the cost difference is enough to discourage the use of these new crops even though they offer significant environmental benefits," says Evan Hughes, EPRI's manager for the project. These benefits include the absorption of carbon dioxide by the crops, which offsets emissions of fossil-fuel-generated CO_2, and a reduction in emissions of sulfur oxides and possibly even nitrogen oxides.

A major thrust of the university's current research is making the poplars resistant to Roundup, a widely used herbicide. "Controlling weeds is particularly critical for the success of poplar plantations," says Steve Strauss, a forestry science professor at Oregon State University and the director of the university's Tree Genetic Engineering Research Cooperative (TGERC), which is conducting the jointly sponsored research. "Effective weed control enables the trees to grow more rapidly and reduces costs." The use of less-effective herbicides entails higher costs because they must be applied more frequently and because any remaining weeds must be removed mechanically.

Before the advent of genetic engineering, the only way to produce an herbicide-resistant poplar was to search through millions of existing poplars to locate those with the most resistance, says Strauss. Buds or cuttings from those trees could then be used to propagate new trees. But the selection and breeding processes are very time-consuming, and the results are far from certain. Hence, concludes Strauss, "this method is, for all practical purposes, impossible."

In contrast, genetic engineering enables scientists to extract herbicide-resistant genes from an entirely different organism. At Oregon State University, researchers are working with a gene found in *Agrobacterium*, a genus of natural soil bacteria commonly found around plants. Some strains of *Agrobacterium* can thrive in the presence of very high concentrations of Roundup. The herbicide-resistant gene is extracted

Transgenic poplar shoots arising in tissue culture

from the bacteria in the laboratory on a cellular level, and its DNA is engineered to resemble a plant gene so that it can carry out its herbicide-resistant function in poplar cells. In addition, the researchers insert a gene that actually degrades the herbicide. The engineered genes are introduced to the poplar cells in a petri dish.

At this writing, the university researchers are applying Roundup to poplar plantations containing trees that have been genetically engineered to resist the herbicide. Researchers will closely monitor the trees' growth to determine the success of the experiment. They are using similar genetic engineering techniques to encourage insect resistance and sterility in poplar plantations. Developing poplars that don't produce seeds will prevent them from crossbreeding with native trees in surrounding areas and will preserve more of the poplars' energy for growth.

TGERC, which EPRI joined last year, was established in 1994 and is expected to continue at least until 1999. The effort builds on knowledge gained by the pulp and paper industry.

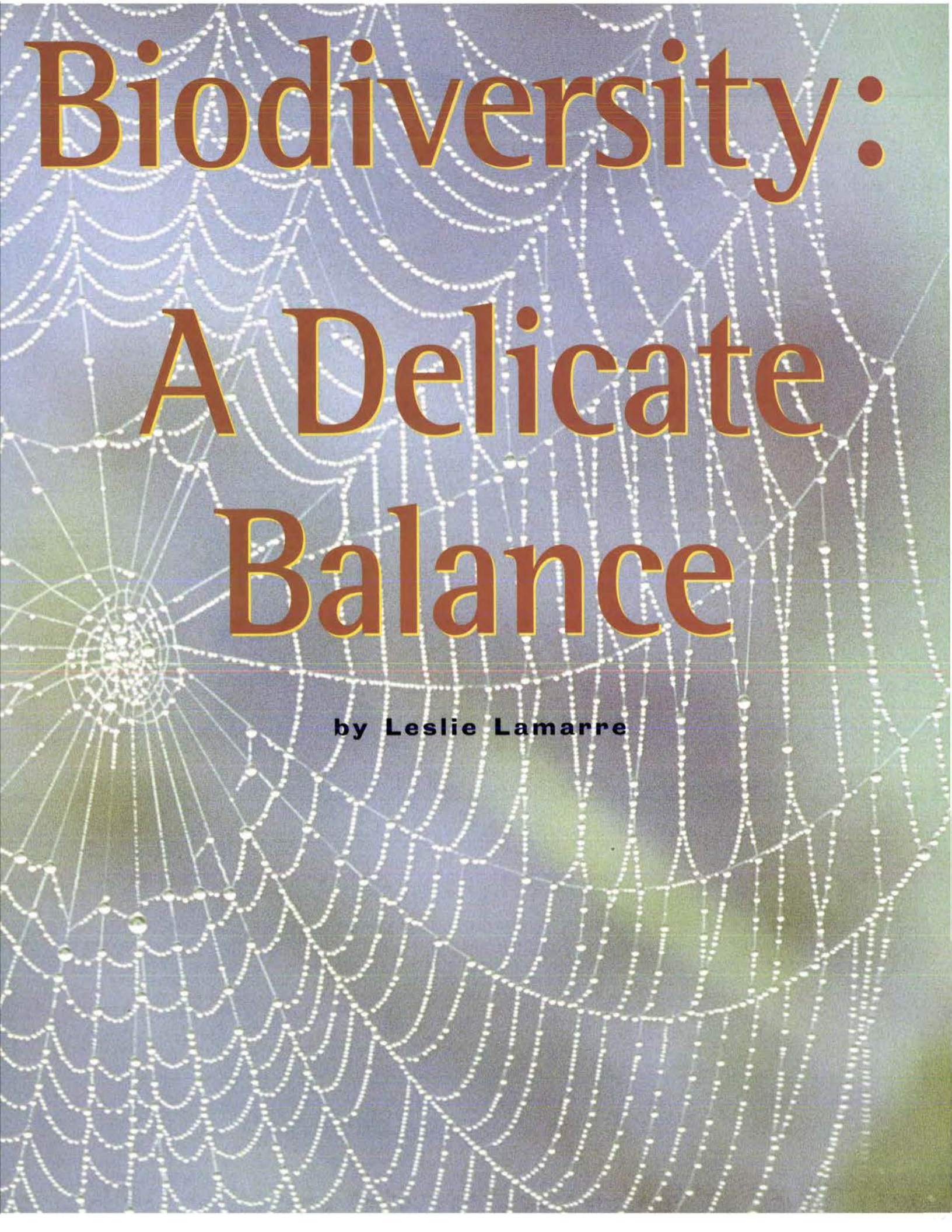
■ *For more information, contact Evan Hughes, (415) 855-2179.*

Preserving

THE STORY IN BRIEF

Like the threads of a spider's web, diverse species in a natural region are interdependent. Just as the loss of a single thread in a web can weaken the whole structure, the loss of an individual species can disrupt an entire ecosystem. Electric utilities are becoming increasingly aware of the value of diverse ecosystems, and a number of power companies have initiated programs designed specifically to preserve and enhance biodiversity. Such programs go beyond traditional environmental efforts: they account for the well-being of entire habitats rather than focusing strictly on individual species. As representatives at EPRI's recent biodiversity conference stressed, this broader mission calls for a range of expertise that can only be acquired through partnership. Indeed, a variety of stakeholders—including industry, conservation groups, government agencies, and community members—are teaming up on the biodiversity issue. Some are calling on utilities to take the lead.

PETER



Biodiversity: A Delicate Balance

by Leslie Lamarre

THE BENEFITS OF BIODIVERSITY **Although aesthetics and recreation are the most widely recognized advantages of diverse and healthy ecosystems, biodiversity serves a more fundamental role in our everyday lives. For instance, natural processes such as water filtration and pollination work to clean and replenish vital natural resources. And diverse plant species provide critical ingredients for about a third of today's prescription drugs.**

When John Sawhill, president and CEO of the Nature Conservancy, gave a speech on biodiversity to an electric utility audience five years ago, he says he got a lot of blank looks. Times have certainly changed. Sawhill recalled this observation at a recent conference on biodiversity sponsored by EPRI on behalf of its electric utility members—an event at which he praised utilities for their efforts on the issue. Held this March in Williamsburg, Virginia, the two-day conference, called Managing for Biodiversity,* was a milestone for utility involvement in biodiversity. But perhaps just as significant was the fact that the conference drew together leaders from academic, government, conservation, and industry groups to collaborate on an issue that once set them apart.

It may seem odd for the industry to address biodiversity at a time when increased competition is demanding attention to the bottom line and forcing many companies to trim back environmental budgets. But a number of utilities share a different perspective. Many of them have found that the working relationships they've established with government agencies and environmental groups have enabled these entities to better understand the constraints of the utility industry. Others say their environmental programs not only have made their companies look good but also have saved money and helped avoid litigation. Still others speak of the industry's responsibility for environmental stewardship, given its significant land holdings, its large water use, and its ability to have a major impact in this area. This responsibility was underscored by James Pipkin, counselor to the secretary of the interior and a keynote speaker at the biodiversity conference: electric utilities, he said, "manage facilities that literally reach into every household and every business in the nation. As an industry, they wield far-reaching economic, social, and political influence."

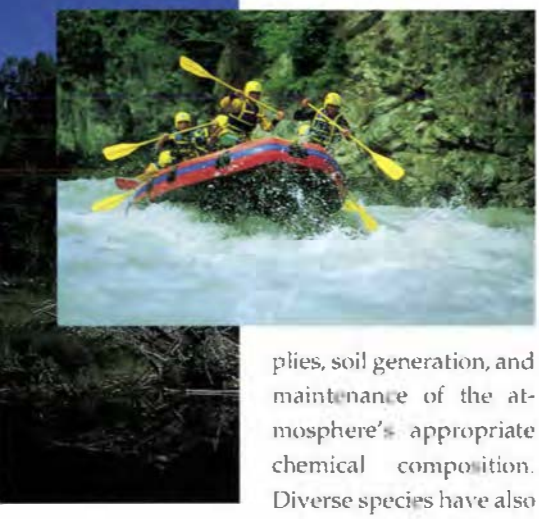
But beyond these reasons for getting involved in biodiversity is what many in the electric utility industry consider the biggest reason of all: if the industry misses its opportunity to get involved at this early stage, it runs the risk of its concerns being overlooked when relevant environmental regulations—such as carbon emissions limits or revisions to the Endangered Species Act—are discussed. "Electric utilities can sit on the sidelines, watch what happens, and react, or they can be proactive, get a seat at the table, and work with people to come up with policies and regulations that take the industry's concerns into account," says Jack Mattice, a manager with EPRI's Environment Group and one of the organizers of the conference. Indeed, as Sawhill put it, getting involved now is a way for the utility industry to "control its own destiny."

What is it anyway?

Biodiversity is a term that has emerged in recent years to describe the rich variety of plant and animal species in a natural region. Wide use of the word in the popular press—particularly since the 1992 Earth Summit in Rio de Janeiro—has practically made it a household term, alerting society at large to the urgency of the issue.

Why is preserving biodiversity so important? Like the threads of a spider's web, individual species within an ecosystem are interdependent. Just as the destruction of individual threads within the spider's web can weaken connecting threads and—if enough threads are lost—even threaten the integrity of the entire web, the disappearance of individual species from an ecosystem can harm the species that rely on them for survival and ultimately weaken the entire ecosystem. Productive ecosystems teeming with wildlife are not only important in terms of aesthetic and recreational benefits. Diverse and healthy ecosystems also provide critical ecological benefits, such as plant pollination, freshwater sup-

*A summary of the conference and some 20 peer-reviewed papers presented there will be published in a special issue of *Environmental Management* (Volume 20, Number 6, November/December 1996).



plies, soil generation, and maintenance of the atmosphere's appropriate chemical composition. Diverse species have also been a boon to modern medicine. For example, cyclosporine, developed from a soil fungus, revolutionized heart and kidney transplant surgery by suppressing the immune reaction. In fact, according to the Wiley Encyclopedia Series in Environmental Science, one in ten plant species contains some type of anticancer substance and about a third of all modern prescription drugs contain compounds from plants—compounds that the plants developed to defend themselves against various diseases. At this time, scientists know only a small fraction of these valuable species, some of which are lost every year.

All facets of the daily operations of electric power companies—from water discharges and atmospheric emissions to dams and transmission line rights-of-way—can negatively affect biodiversity. The construction of facilities necessary for the generation and delivery of electricity requires that lands be cleared of vegetation and—in the case of hydropower—that river flows be altered by dams. But since the industry is undertaking fewer construction projects at this time, the primary focus for electric utilities involved in biodiversity is on activities related to the operation and maintenance of existing facilities, such as power plants, dams, and electricity transmission and distribution systems. Integral to this focus is the creative management of the extensive land and water resources that utilities require for their daily operations. Relevant lands include right-of-way swaths, the buffer zones of undeveloped land surrounding power plants, and sites purchased for power plants and other projects never built. Water resources include utility reservoirs, water used in power plant operations, and water that turns hydroelectric turbines, which supply 10% of the country's electricity. Mattice stresses that aquatic species should not be overlooked in the biodiversity equation, since about 45% of the endangered and threatened species in the United States are aquatic.

New sensitivities

Over the years, a number of electric utilities have sought to alleviate or offset the environmental impact of their businesses not just by meeting existing environmental regulations but also through voluntary programs to preserve and enhance the natural environment. These programs have ranged from tree-planting ventures to energy efficiency measures. The most recent programs reflect an increased sensitivity toward preserving biological diversity and are characterized by a more holistic focus. Rather than targeting individual species, such programs consider habitats and ecosystems; instead of examining individual rivers and lakes, they consider entire watersheds.

A recent survey of utilities in the United States and Canada confirms that utilities are beginning to pay attention to biodiversity. Conducted by the Southern Company, Carolina Power & Light, and Duke Power, the survey showed that 54% of the respondents consider biodiversity an issue for their companies, 39% have designated a person to track the issue, and 19% are involved in research on the issue. Some 75% said that biodiversity should be a goal for utility resource management, and 59% feel that the industry should be more involved with biodiversity research. At this time, only 24% of the respondents have environmental policies that address biodiversity. "While biodiversity may not be specifically mentioned in utilities' environmental policies, natural resource enhancement or wildlife conservation is generally included and may be interpreted as biodiversity by some but not by others," says Gary Breece, assistant to the vice president of environmental policy at the Southern Company. The survey drew responses from 64 utilities in the United States and Canada. The 59 U.S. utilities that responded rep-

Duke Power's operation of the Wylie hydro plant on the Catawba River in South Carolina enables the native Piedmont spider lily to thrive downstream from the dam.

During the winter, endangered manatees are drawn to the warm-water discharge at Tampa Electric's Big Bend station. The utility operates an environmental education center where the public can view the manatees.

resent about 64% of the electricity generated and some 60% of the area served by the electric utility industry in this country. The 5 Canadian utilities represent over half of that country's electricity generation and service area.

An increased sensitivity toward biological diversity involves paying close attention to the potential for ecosystem impacts. For instance, some utilities have traditionally stocked transmission corridors with wild turkeys, quail, and other game species, just as they have stocked rivers and reservoirs with fish like salmon and bass. Although these practices appear to be a positive step for recreational hunting and fishing, they should be exercised with caution, since they can pose a threat to the "less charismatic" species and could even push such species out of their native environments. "There is a clear need for information and further research on the response of native or endemic biota to such introductions," says Mattice. "At this time we do not know all the answers."

BEETLE: BRUCE WRIGHTSMAN/PHOTO RESEARCHERS INC

PARTNERSHIPS FOR PRESERVATION
Voluntary partnerships with environmental groups like the Nature Conservancy have helped electric utilities ensure that they properly address the complex and varied needs of native species and their habitats.

This concern also extends to plant species that utilities introduce. While environmentalists have praised the electric utility industry's use of biomass to fuel power plants because it is a renewable fuel source, there is a concern that the large-scale planting of renewable biomass crops in biologically diverse terrain will drive out species that are native to the area. For this reason, it is important for biomass crops to be planted on already homogeneous, idle land, such as sites formerly used for intensive agriculture.

Partnering for a purpose

Because of the sensitivities involved in the biodiversity issue, it's important that utilities communicate with a broad range of experts. This is largely why collaborative relationships among utilities, environmental organizations, government agencies, and community groups are becoming more common in environmental planning. Indeed, partnerships of this kind are forming the foundation of the biodiversity movement currently under way. Not only do the partnerships tap the valuable knowledge of the various experts in-

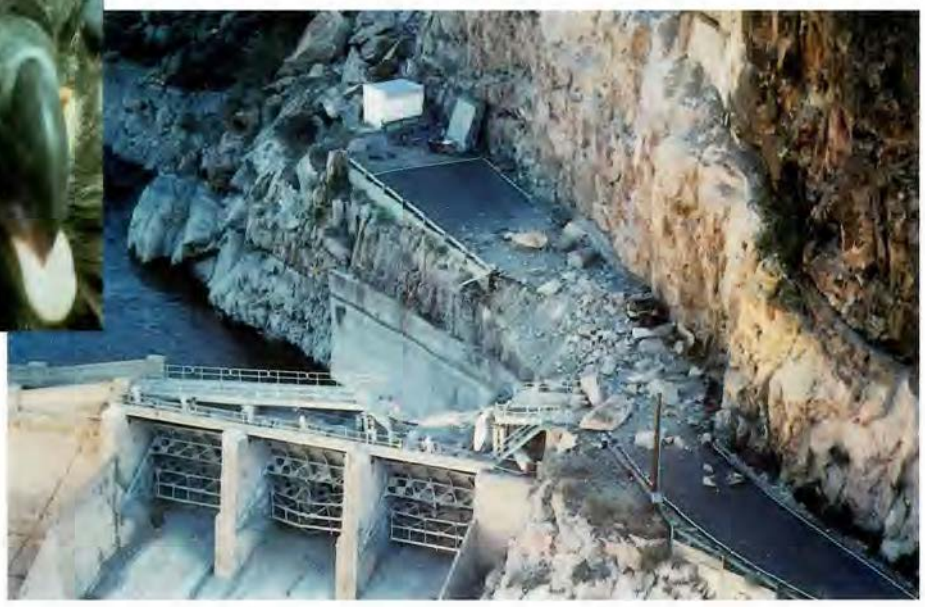
Baltimore Gas and Electric has worked with the conservancy to monitor endangered tiger beetles that live in the beaches and dunes around the utility's Calvert Cliffs nuclear plant.

Public Service Electric and Gas of New Jersey is working with the conservancy to restore the health of the Delaware Bay.

JEFF LEPORE

volved in the biodiversity issue, they also distribute the financial burden of biodiversity efforts among many participants, cut down on duplicate research efforts, and reduce the risk of conflict later on.

JAMES T. BURSCHELL



GOOD RELATIONS **The Salt River Project collaborates with state and federal agencies and Native Americans to protect desert-nesting bald eagles in Arizona. When a major rock slide occurred at the utility's Horse Mesa Dam some 200 feet below the nest of a pair of eagles, SRP worked with wildlife experts from these groups to determine how best to resolve the problem. Agreeing to hold off on blasting and to operate heavy equipment carefully, the utility was able to enter the area to clear the site.**

Utilities have teamed up with knowledgeable partners on a wide range of projects, from routing transmission lines around sensitive areas to managing the flow of water through dams. Several such efforts were highlighted by John Sawhill at the biodiversity conference. For example, Baltimore Gas and Electric has worked with the Nature Conservancy at the Calvert Cliffs nuclear plant, located in a region that supports 90% of the population of the endangered puritan tiger beetle. Together, the utility and the conservation organization developed a monitoring program to ensure that the beetle will continue to thrive. In another effort, Public Service Electric and Gas of New Jersey and the conservancy are jointly managing 15,000 acres of utility-owned land along the Delaware Bay to improve the health of the Delaware Estuary by restoring tidal flow to areas that have been diked and drained. And several years ago, Duke Power came to the conservancy for help in siting a transmission line through Panthertown Valley, North Carolina—an ecologically valuable region. The utility was able to engineer a route for the power line that avoided regions inhabited by endangered species as well as scenic areas popular with the public. Duke even installed transmission towers by helicopter to avoid disturbing habitat by road cutting.

Often utilities and their partners share valuable information and in-kind services, as was the case when Georgia Power assisted the Nature Conservancy with a major mapping project on the Altamaha River. In return, the conservancy provided the power company with something it needed—biological inventories on company-owned property along the river. Protecting the natural environment of scores of native and often rare species, from the peregrine falcon and the manatee to the Piedmont spider lily and the Karner blue butterfly, has been the focus of numerous collaborative efforts involving utilities. Utilities have also opened up ecologically significant land within their service territories to share with the public, establishing nature trails and natural history museums. Community members have responded enthusiastically to such efforts and encourage utilities that cannot afford a significant financial commitment to consider other types of assistance, such as the provision of a meeting place or even refreshments. As Jo Clark of the Western Governors' Association puts it, "A cup of coffee goes a long way."

Working in partnership with a broad range of interests isn't always easy, but many power companies are finding the extra effort worthwhile; not only does such collaboration help utilities understand the needs of other stakeholders, but the other stakeholders learn to appreciate the pressures utilities face, too. For example, the Salt River Project participates in a voluntary cooperative effort—involving state and federal agencies and Native American tribes—to protect

COURTESY NIAGARA MOHAWK

Niagara Mohawk Power has funded research on right-of-way management practices that support the endangered Karner blue butterfly.

desert-nesting bald eagles in Arizona. Two years ago, a major rock slide at one of SRP's dams blocked a nearby road. The incident happened to occur during the eagles' five-month breeding season, and one pair of the birds had established a nest a couple of hundred feet above the dam.

Government biologists determined that any blasting in the region was certain to be disruptive to the eagles but that the operation of heavy equipment—if conducted carefully—could be undertaken. The utility agreed to hold off on blasting but was able to send a crew into the area to clear the debris and secure the rock face. The most rewarding outcome was that the nest was successful. "It would have been very easy for Arizona Game and Fish and the U.S. Fish and Wildlife Service to say, 'You can't get in there because it's breeding season,'" says Teah Nobel, who manages SRP's involvement with the bald eagle project. "But I think that because of our cooperative efforts, we were able to get in and take a look at what we could do." The collaborative bald eagle program has been credited as a catalyst in the downlisting of the eagle from "endangered" to "threatened" in Arizona last year.

MANAGING DIVERSE INTERESTS The Western Area Power Administration, which sells and distributes power produced at the Bureau of Reclamation's Glen Canyon Dam, is among an increasing number of utilities that are finding they need to balance social interests with environmental and economic concerns. The adaptive management process proposed for the dam seeks to protect the humpback chub, an endangered species native to the Colorado River, while satisfying the desires of the river's varied stakeholders, including white-water rafters, farmers, Native American groups, and municipalities.

Utilities Offset Emissions, Preserve Biodiversity in Central America

The keel-billed toucan, the national bird of Belize, is one of more than 380 bird species native to Rio Bravo.

Some electric utility efforts to preserve biodiversity have extended beyond U.S. borders. For instance, a group of U.S. power companies is helping to conserve and manage a 120,000-acre tropical forest in northwestern Belize. Called Rio Bravo, this forest is home to over 380 bird species and 12 endangered mammals. All 5 of the Central American cat species, including the jaguar and the puma, also live there. Rio Bravo abuts two other major reserves, creating the largest remaining block of forest in Central America.

The overall aim of the Rio Bravo project—sponsored by Wisconsin Electric Power Company, Detroit Edison, Cinergy, PacifiCorp, and UtiliTree Carbon Company, working in conjunction with the Nature Conservancy and a nongovernment organization in Belize called Programme for Belize—is to voluntarily offset some of the electric utilities' emissions of carbon dioxide, which is believed to cause global warming. (CO_2 emissions are not yet regulated.)

The project involves the purchase of a 14,400-acre parcel of tropical forest, which otherwise would be lost to agricultural use, and the implementation of a plan for sustainable forestry on an adjacent 110,000-acre parcel. "In order to protect this land over the long term, it has to provide an economic benefit to Programme for Belize, the owner of the property," says Noel Cutright of Wisconsin Electric Power. "Otherwise, the land will be converted to the highest-value short-term economic use—large-scale intensive agriculture." The conversion of such ecologically valuable land to intensive agriculture would destroy the region's rich mix of animal and plant species, replacing it with an environment that is virtually a monoculture. Protecting and managing this forested region not only will help preserve its biodiversity but also will enable the forest to store some of the CO_2 that would otherwise escape into the atmosphere. The project is expected to capture more than 5 million tons of CO_2 over a 40-year period.

The Rio Bravo project is among the first joint implementation (JI) projects initiated by organizations from the United States. A concept introduced during the discussions leading up to the 1992 Earth Summit, JI describes a wide range of international projects through which organizations in various countries collaborate to reduce greenhouse gases—particularly CO_2. JI has been formally adopted into the text of the United Nations Framework Convention on Climate Change. □

Regulatory trends

Experts on all sides of the environmental debate are shifting their focus from individual species to habitats and ecosystems. Many have expressed frustration with the Endangered Species Act (ESA), which was established to help preserve the earth's rich mix of diverse species. A key problem is that the ESA singles out species rather than entire communities or habitats, and protection is sought for those species only when they are on the brink of extinction. As James Pipkin puts it, "To try to save the species without dealing with its habitat is like treating the symptom and ignoring the illness." Also, from a private landowner's perspective, little incentive exists to identify rare species on a given site; rather there is fear that such a finding could halt existing operations or plans for developing the site. In the words of Mark Sagoff, a professor with the Institute for Philosophy and Public Policy at the University of Maryland, this encourages a mentality of "shoot, shovel, and shut up." Says Sagoff, "The confrontation has got to give way to cooperation one way or another."

MIKE COUFFER/GREY OWL PICTURES, INC.

FOCUS ON HABITAT

Emerging regulations geared toward preserving biodiversity aim to protect entire habitats rather than individual species and to offer greater flexibility to landowners. For instance, habitat conservation plans (HCPs) are long-term agreements for protecting ecosystems while enabling economic use of private lands. Southern California Edison is one of 11 landowners participating in an HCP established to protect coastal sage scrub habitat and 42 of the species that live there, including the coastal cactus wren (left), the California gnatcatcher (right), and the orange-throated whiptail lizard.

Greater cooperation is exactly what is emerging through some new regulatory approaches that are being introduced—approaches that not only focus on conserving biodiversity by specifying the protection of habitat but also offer greater flexibility to landowners. One such approach involves the establishment of habitat conservation plans (HCPs)—long-term agreements aimed at protecting communities or ecosystems while enabling economic use of private lands. "The Clinton administration has recognized that implementation of the Endangered Species Act can be improved by exercising greater administrative flexibility to minimize socioeconomic effects and ensure fair treatment for landowners," Pipkin explains. HCPs typically specify an approach for protecting multiple species and their habitat while allowing for some business activity in a given region, and they usually involve some level of financial support from the landowner. Those who collaborate with government agencies to develop these plans are not subject to later demands for more money or land to conserve the species. Says Pipkin, "A deal is a deal, and development can proceed without the prospect of additional mitigation requirements."

One of the first HCPs to be established involves the participation of 11 landowners in Orange County, California, including Southern California Edison. This HCP, developed as part of the pilot program of the state's Natural Communities Conservation Planning Act, was established specifically to protect coastal sage scrub habitat and 42 of the species that live there, including a tiny songbird called the California gnatcatcher, which has been listed as threatened since 1993. Approved in July, the pilot program establishes a 39,000-acre reserve made up primarily of land contributed by the participating landowners. These participants have also contributed a total of $10.6 million in mitigation fees that will be placed in an endowment. Interest from the endowment will cover the reserve's yearly budget for management, including a reserve manager and two staff biologists. A nonprofit board of directors (composed of representatives of the landowners, Orange County, the California De-

partment of Fish and Game, the U.S. Fish and Wildlife Service, and the community) oversees the reserve's operation. Landowners will receive permits for current and future projects identified in the HCP. Those not electing to participate in the program will have the future option of paying a per-acre mitigation fee or developing their own HCP.

The land Southern California Edison has contributed to the reserve includes two transmission rights-of-way, one of which is 500 feet wide and consists of 94 acres that are designated to link habitat in the reserve with another planned conservation area. In return, SCE will receive a permit for operation and maintenance activities associated with this line. The second right-of-way lies within the reserve and consists of a 105-acre linear parcel. SCE will get a permit for the operation and maintenance of existing lines on this right-of-way and for any impacts related to the installation of several future transmission structures associated with a planned substation to be located on property adjacent to the preserve. Although the bulk (99 acres) of this parcel will soon be sold, the utility has agreed to sell only to a party that will keep it in the reserve.

Several southeastern utilities have worked with local conservation departments to inform the public that reducing beach lighting during the months when sea turtles hatch increases survival rates.

San Diego Gas & Electric created its own subregional HCP aimed at protecting biodiversity in coastal sage scrub and other habitats, including pine forests. This plan specifies the protection of 110 species throughout SDG&E's service territory, including the Cal-

Research Addresses Biodiversity Needs

Determining how best to preserve and enhance biodiversity in a competitive business environment is no easy task. Policymakers on all levels—from local to regional to global—need answers to critical scientific questions in order to make the best decisions.

Fortunately, research organizations like EPRI and other groups concerned about the biodiversity issue are getting an early start. "We are at a great advantage with biodiversity because the topic has only recently emerged and is just beginning to take shape as a public policy issue," says Myra Fraser, EPRI's manager for wildlife and terrestrial ecology, who was part of the team that organized the Managing for Biodiversity conference held in Williamsburg, Virginia. "This means we can work to ensure that biodiversity research addresses the questions that are most critical to the needs of decision makers." Ensuring that scientific research addresses decision makers' needs is precisely the goal of the Biodiversity Uncertainties and Research Needs (BURN) project, which is funded by the U.S. Environmental Protection Agency, the Bureau of Land Management, the Department of Energy, International Paper Company, the National Biological Service, the U.S. Forest Service, and EPRI.

The Automated Wildlife Surveyor (AWS), shown here with an optional photovoltaic system, uses microphone technology to monitor wildlife.

A researcher analyzes patterns resulting from AWS recordings of frogs in the wild.

The BURN project has involved interviews with some 100 decision makers in government and nongovernment organizations operating at local, state, regional, national, and international levels. The group included natural resource and land managers, members of environmental quality groups, and policymakers from public organizations like the U.S. Senate Energy and Natural Resources Committee as well as private organizations like the Environmental Defense Fund.

Armed with the information gathered on the specific needs of these decision makers, the BURN project sponsors commissioned 30 leading natural and social scientists to examine the needs and identify which of the issues scientific research could address. A workshop then brought the scientists and decision makers together to examine the research that would be required to address decision makers' needs and determine the probability of success. Results will be published in a report that is expected to be released this fall and will be available through EPRI. The document will serve as a guideline that EPRI, the federal government, and others can use to help steer the course of biodiversity research into the most useful areas.

In the meantime, research organizations like EPRI are progressing with projects already under way. The following are just some of the tools EPRI has developed to assist with the biodiversity issue.

■ **Automated Wildlife Surveyor** Developed as a more efficient and cost-effective means than traditional approaches to monitoring wildlife populations (such as manual on-site observations), this device is designed to be left unattended at the

ifornia gnatcatcher, the San Diego horned lizard, and the northern red rattlesnake. According to Don Rose, senior land planner for the utility, the service territory incorporates 75% of the country's remaining coastal sage scrub habitat, and this type of vegetation occupies most of the land that is left to be developed for such uses as housing and utility projects.

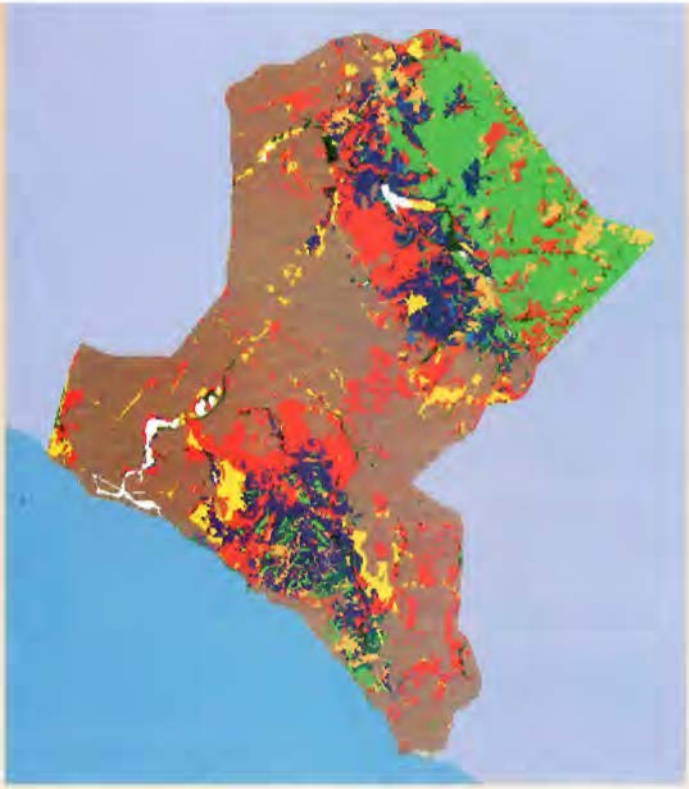
Under the plan, which was approved in December and is currently administered by the U.S. Fish and Wildlife Service and the California Department of Fish and Game, none of the regular permits typically required by the ESA will be necessary. Instead, the utility can—over a 25-year period—disturb up to 400 acres (about half a square mile) of natural area within its 4000-square-mile service territory for routine projects like the use, maintenance, and repair of existing gas and electric systems, as well as typical expansions of these systems. To compensate for the areas disturbed in the course of such routine projects, SDG&E has purchased 240 acres of other natural land that will serve as a "mitigation bank." If the utility uses up more than these 240 acres, it must purchase additional mitigation land. And if any more than 400 acres of natural area are disturbed over 25 years, the agreement must be revisited. However, only 124 acres are expected to be disrupted during this time frame.

The plan does not allow for more-significant expansions of SDG&E's system, such as new power plants (which still have to be evaluated on a case-by-case basis). Since avoidance of impact is the primary thrust of the plan, field crews are required to attend regular classes about working in environmentally sensitive areas. Also, as part of the agreement, SDG&E must provide certain rights-of-way for use as wildlife corridors to connect the region's conservation areas. SDG&E considers the HCP approach much more time-efficient than obtaining ESA permits on a project-by-project basis. And the approach offers the certainty that the utility

location of the species being monitored. An array of sophisticated microphones and a computer equipped with noise pattern recognition software help gather information up to 24 hours a day on single or multiple species. The data are then processed using an artificial intelligence system.

■ **RAMAS codes** The RAMAS library of ecological software was developed specifically to help utilities perform biodiversity risk assessments. Users can construct and analyze models of single and interacting species populations. Applicable to aquatic and terrestrial plant and animal species, the software can predict species abundances and fluctuations, spatial and temporal population distributions, and extinction probabilities. The series currently includes three main codes: RAMAS/age, RAMAS/stage, and RAMAS/GIS.

■ **Watershed Analysis Risk Management Framework** Wetland degradation, water diversion, urbanization, and other factors continue to disturb fish-spawning habitats, nursery grounds, and the overall biological integrity that determines water quality. This model, a useful aid in watershed management, can help utilities and other stakeholders identify where and when water quality problems may occur in a given river basin. The model helps users pinpoint causes of specific environmental problems and derive cost-efficient, environmentally effective solutions.



This map from RAMAS/GIS shows the distribution of coastal sage scrub and other vegetation in Orange County, California.

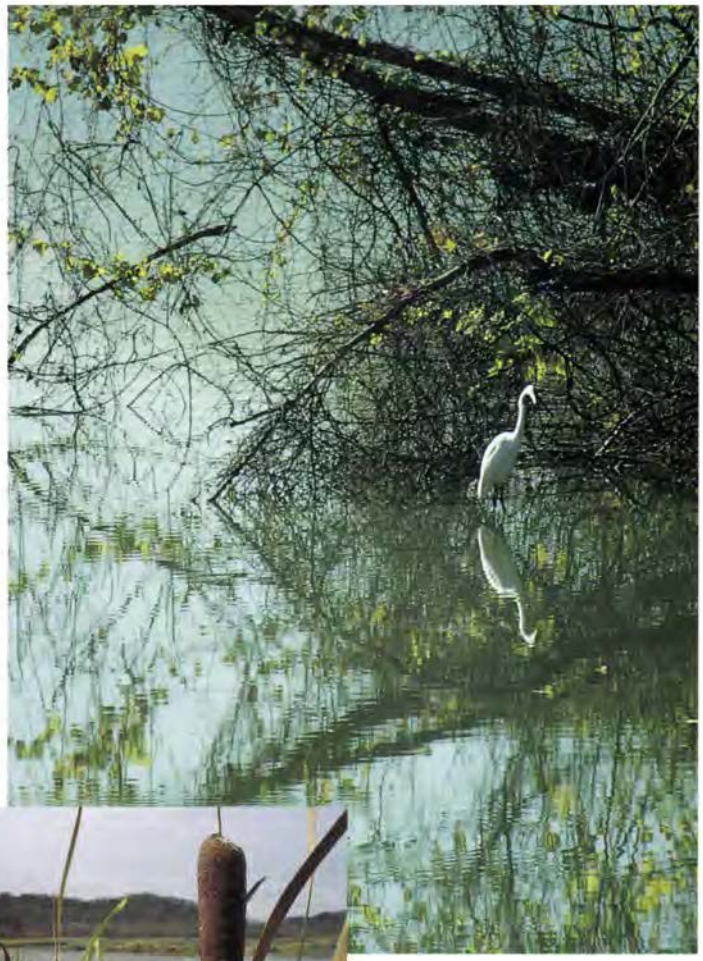
■ **Climate change report** This EPRI study (TR-103330) represents a first attempt to identify the vascular plant species in the United States and Canada that might be especially vulnerable to climate change. The report estimates the magnitude of the threat imposed by climate change and presents a means of identifying endangered plant species that might suffer from increases in mean annual temperatures. Such information can be used to develop conservation plans to protect the vulnerable species.

■ **CompMech models** Expected to be available late this year, this suite of modeling tools was developed to help utilities assess the response of fish populations to such power plant impacts as impingement on intake screens and turbine blades and exposure to warm-water discharge. Applicable to the spectrum of North American fish species affected by such impacts—including striped bass, trout, walleye, and yellow perch—the models can be used to compare the consequences of alternative power plant operating scenarios and can even aid utilities in evaluating the effectiveness of various mitigation measures. □

will be able to operate and maintain existing facilities and to build new facilities in protected areas. If all goes well, SDG&E will be able to renew its permit for a total of up to 55 years.

Biodiversity—in context

In managing their operations with respect for biodiversity, electric utilities are finding that they must also carefully consider the social implications of their plans for a specific resource. One approach that allows for the consideration of ecological, economic, and social issues in utility planning is called adaptive management. This approach has been proposed for application at the U.S. Bureau of Reclamation's Glen Canyon Dam. While the adaptive management concept is not new, its application to hydropower operations is in its infancy, and its performance at Glen Canyon Dam would be a significant test for the process. A final decision on the proposed plan is expected from the secretary of the interior by early next year.



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CREATIVE RESOURCE MANAGEMENT
Efforts to preserve and enhance biodiversity can go beyond simply being careful not to disturb the natural environment. In 1993, American Electric Power built a new habitat, Gavin wetlands (bottom), to provide a stable home for various native species. In another case, AEP helped preserve the Sandusky Bay wetlands (top) by transferring ownership of that natural habitat to the state of Ohio.

Located on the Colorado River in Arizona, just north of the Grand Canyon, the Glen Canyon Dam controls the flow of a water resource sought by many types of users, including white-water rafters, trout anglers, farmers, municipalities, and Native American groups. The construction of the dam has had negative environmental impacts, including the prevention of big-river fish species from moving upstream. But there have been some positive results too, particularly regarding biodiversity. In fact, significant improvement in biodiversity downstream of the dam was among the findings reported in an environmental impact statement released by the Bureau of Reclamation. For instance, marshland, which was formerly rare in the Grand Canyon, has developed downstream of the dam because of a more stable annual river flow. And areas once barren because of annual spring flooding are now colonized by vegetation. Because Lake Powell, the reservoir above the dam, acts as a sediment trap, downstream water clarity has increased; this has enabled diverse new aquatic plants and related insects to establish themselves, providing a food base for other insects, lizards, bats, and birds. Some of these new and diverse species are prey of the endangered peregrine falcon, which has as a result become more prevalent in the Grand Canyon.

The primary aims of the adaptive management plan for this site are the recovery of the humpback chub, an endangered fish species native to the river, and the management of the many interests in the dam. However, says Mark Wieringa, an environmental protection specialist for the Western Area Power Administration, the utility that sells and distributes power produced at the dam, "It is assumed that if certain natural resources are protected through proper management decisions, modified as appropriate through the adaptive management process, then the increased biodiversity of Glen Canyon and the Grand Canyon should be protected as well."

Under the proposed plan, those providing input through the adaptive management process would include federal and state agencies, state governors, Native American tribes, academic and scientific communities, environmental organizations, and the recreation industry. A working group composed of representatives of the various interest groups would be responsible for the plan's framework and management direction. A technical group made up of experts from each of the participating entities would take the policies and goals developed by the working group, translate them into resource management objectives, and recommend specific actions. An independent monitoring and research center administered by the U.S. Geological Survey would coordinate the monitoring and research needed to meet the plan's objectives. Finally, a review panel, also independent, would provide a quality check for the plan.

Adaptive management is attractive because it emphasizes the role of science as a basis for decision making. But there are drawbacks too. After all, science itself can

be subject to interpretation, and contentious issues can remain contentious. The decision process can also be expensive and time-consuming. Nevertheless, with so many competing interests for water resources today, a collaborative management process involving input from various users is almost mandatory for utilities with hydro plants. Wieringa says, "Hydropower plant operators who ignore other views and values in the operation of their facilities risk incurring the wrath of river and reservoir users, as well as damaging natural resources."

Competition factor

A more competitive business environment is encouraging utilities to listen closely to their many stakeholders. "Electric power providers are not nomadic businesses that can easily pick up and move to other parts of the world. Rather, they depend on long-term relationships with the communities they serve—communities and consumers that have a vital interest in the protection of regional land and water," says Kurt Yeager, president and CEO of EPRI. "Especially when consumers have a choice, as they will in our increasingly deregulated business environment, energy providers who disregard their environmental stewardship do so at their own considerable peril."

In some cases, the pressures of competition are increasing the incentives for utilities to dedicate land to conservation, thereby benefiting biodiversity. Historically, many companies have maintained vast property holdings in order to have land for future generation projects. In today's more competitive environment, such a land management strategy is neither practical nor prudent. Instead, utilities with large land holdings are seeking ways to improve shareholder value through the gradual and deliberate disposal of these land assets. Resulting land divestitures include efforts to protect ecologically diverse and valuable property. For instance, Duke Power worked with the Nature Conservancy to sell 6000 acres of Panthertown Valley, North Carolina, to the U.S. Forest Service, helping to ensure that this area—sometimes called the Yosemite of the East—will be preserved. In a similar deal, Duke worked with the North Carolina Wildlife Resources Commission and the Nature Conservancy to sell the commission over 5000 acres along the Green River in upstate North Carolina—a scenic and biologically rich natural area.

Despite the incentives that exist for enhancing biodiversity, the mounting competitive pressure forcing electric utilities to focus on the bottom line is generating some very real fears that environmental budgets may shrink significantly. Indeed, many utilities have experienced drastic cutbacks in the environmental area. Those involved in utility environmental programs urge others to document any savings resulting from their efforts. Dick White, vice president for environmental services at TU Electric, says he has established a system that encourages his staff to report such dollar savings. According to White, records for 1995 show that his environmental services staff saved the company $19.5 million—nearly $5 million more than the staff's $15 million budget for that year. "Keeping track of what you do and what the savings are is something every one of you needs to be doing," said White, addressing utility representatives at the Managing for Biodiversity conference. "You must communicate these savings to the business groups that you support. They are your clients, and they need to know that your programs are cost-effective."

Georgia Power, Alabama Power, Carolina Power & Light, and Northern States Power are among the utilities that have participated in peregrine falcon recovery programs.

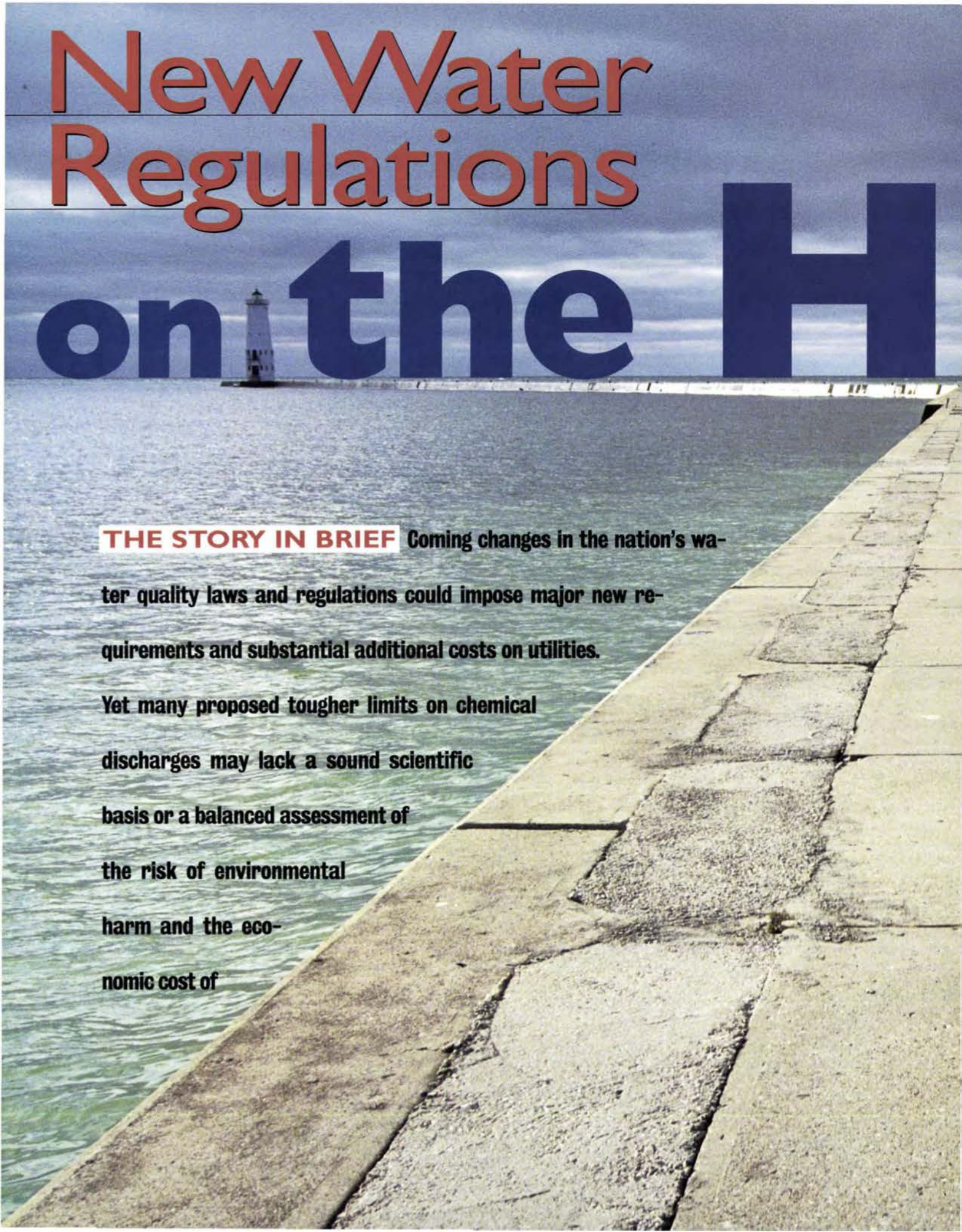
The support of upper management has been repeatedly cited as essential to the foundation of a successful ecological mission. Dale Heydlauff, vice president for environmental affairs at American Electric Power, says that AEP has gone through two major restructuring periods and in both instances wound up with more people on its environmental staff. Heydlauff notes that environmental leadership is one of the company's corporate goals. AEP's wide-ranging environmental projects include a number that offer direct benefits to biodiversity—the creation of new wetlands and the enhancement of existing ones, for example, and the donation of ecologically valuable land to conservation organizations. "Maybe we're just lucky that we've got a CEO with a high degree of environmental consciousness," says Heydlauff. "He puts a high priority on these issues. But I actually believe this is the prevailing environmental ethic of the industry today."

Many feel that the current trend toward cutbacks in the environmental area will be short-lived. As W. R. Woodall Jr., vice president of environmental policy at the Southern Company, sees it, the public's high expectations will help keep the biodiversity issue in focus. "Green awareness for corporations is still very real and is a goal for most utilities," he says. "Utilities are still very concerned about what the public thinks of them."

Regardless of whether individual electric utilities feel they can invest in the biodiversity issue at this time, many agree that the industry is well positioned to offer valuable input. "As an industry, we can shape a truly broad, balanced, rational, and cost-effective response to environmental challenges," says Yeager. "I think that electric utilities, with EPRI as the focal point of the industry's R&D, will have to take a position of leadership. It's going to be up to us to provide the basic scientific findings needed to reach consensus on how best to meet the demand for energy while maintaining environmental health and diversity." ■

Background information for this article was provided by Myra Fraser and Jack Mattice of the Environment Group.

New Water Regulations on the H



THE STORY IN BRIEF Coming changes in the nation's water quality laws and regulations could impose major new requirements and substantial additional costs on utilities. Yet many proposed tougher limits on chemical discharges may lack a sound scientific basis or a balanced assessment of the risk of environmental harm and the economic cost of

by Taylor Moore

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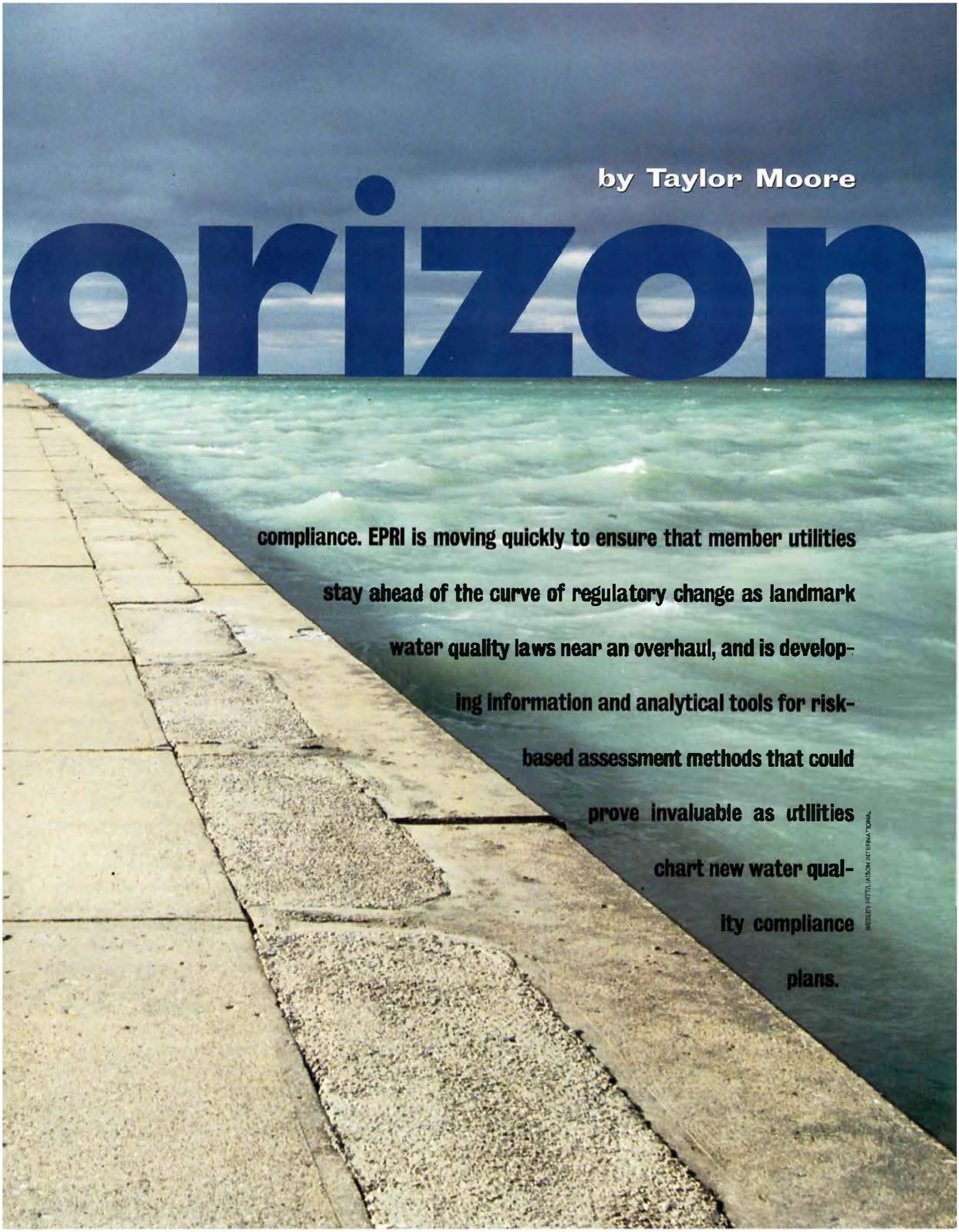


compliance. EPRI is moving quickly to ensure that member utilities stay ahead of the curve of regulatory change as landmark water quality laws near an overhaul, and is developing information and analytical tools for risk-based assessment methods that could prove invaluable as utilities chart new water quality compliance plans.

WESLEY HITT/LIAISON INTERNATIONAL

Many electric utilities are still feeling the economic impact that recent major environmental initiatives—such as those related to the control of emissions that cause acid rain and to the installation of continuous emissions monitors—have had on fossil power generation. Now another wave of legislative and regulatory activity, compliance effort, and potential cost is on the horizon. The first major round of revisions to the nation's clean water laws in a decade is being planned in Congress, at the U.S. Environmental Protection Agency, and by regional commissions and individual states. Whatever changes are eventually enacted, they will almost certainly extend and tighten aqueous pollutant discharge permit limits and other rules that apply to every utility facility that withdraws water from a public source for power plant cooling or other uses.

Cooling intake structures

Plant aqueous discharge streams

As with earlier sweeping environmental overhauls, the economic stakes for utilities—which account for half of total surface freshwater withdrawal in the country—are high. Possible changes include the elimination of the use of chlorine, chemical discharge limits set at or below detection levels, revised intake fish protection performance criteria, and new cooling tower requirements to limit thermal discharges. If all the proposed or suggested revisions are ultimately adopted and applied in the most conservative way, the industry could face as much as $70 billion in additional costs, according to EPRI and industry estimates.

Laws and regulatory programs aimed at improving water quality and maintaining safe drinking water standards have become a battleground of congressional politics in recent years. Efforts to turn back key provisions or to restrict the EPA's authority to carry out responsibilities mandated by previous Congresses have mostly been unsuccessful. Meanwhile, legislation to update the Safe Drinking Water Act was passed by Congress and signed by President Clinton in August. Amendments to the more encompassing and proscriptive Clean Water Act legislation, though stalled in the current congressional session, are likely to come up for a vote next year.

Wastewater ponds

Water treatment systems

Cooling towers

WATER RESOURCES CRITICAL TO POWER GENERATION **Electric utilities, which account for half of total surface freshwater withdrawal, rely on water both for cooling fossil and nuclear power plants and for hydroelectric power generation. In recent years, the focus of water quality management has shifted from controlling point-source discharges of pollutants to managing environmental outcomes and impacts, with trace levels of toxic substances a key issue. Improved scientific understanding of the environmental components of the utility water cycle—water sources, power generation process systems, water impoundments, basins, watersheds, wetlands, streams, estuaries, and oceans—will help inform ongoing policy and regulatory debates.**

Owing to two recent trends that represent something of a departure from the past, water quality policy issues are expected to continue to evolve in an atmosphere of uncertainty over the next few years, albeit with more-favorable prospects for increased regulatory flexibility in implementing new requirements. While rules to protect aquatic and related ecosystems are expected to become more restrictive, the opportunities to apply risk-based assessment methods and cost-benefit analyses of mitigation measures appear to be improving.

The first trend is that, in contrast to the historically Washington-driven, top-down nature of the federal water quality laws and regulatory establishment, the momentum behind the upcoming revisions to the Clean Water Act is largely the product of a regional, transnational organization—the International Joint Commission on Great Lakes Water Quality. Under the aegis of the commission—established by a 1978 treaty between Canada and the United States and composed of representatives of the eight states and two provinces in the Great Lakes Basin—a major review of water quality

standards and requirements for North America's largest freshwater ecosystem has been taking place for several years.

With the EPA's encouragement and cofunding, the review—known as the Great Lakes Water Quality Initiative, or GLI—has introduced a number of important new concepts into the framework for protecting the long-term ecology of the Great Lakes. These concepts are likely to have far-reaching effects on all industries and municipalities that use the resource. Of paramount concern to utilities in the region is a goal of zero discharge of chlorine, whose elimination as a biofouling control agent in power plants would have a substantial operating impact. The initiative has also targeted key heavy metals like mercury and selenium, suggesting possible discharge limits lower than can reliably be detected. For mercury, for example, a discharge limit as low as 0.0013 microgram per liter could be established on the basis of water quality criteria for wildlife protection. The bioaccumulation of various trace chemicals—including heavy metals and organic compounds—in the food chain of animals in a watershed and the quality of bottom sediments far downstream from pollutant discharges are other new areas of concern.

"The Great Lakes Initiative's published intent contains provisions that are more stringent and go much further than the proposed additions to the Clean Water Act," says Bob Brocksen, EPRI target manager for land and water quality, health and risk assessment. "Although the GLI is currently intended only for the Great Lakes, most observers regard it as precedent-setting and believe that the new requirements, methods, and procedures it calls for represent the next generation of national water quality regulations." Indeed, the GLI's integrated watershed management approach and other features are being viewed as a model for other emerging regional water quality initiatives, including one focused on the Gulf of Mexico.

Several states and municipalities in the Great Lakes region have already launched legal challenges to some of the GLI's proposed revisions to water quality standards and required practices. But as matters now stand, the states have until March 1997 to initiate or develop plans for implementing provisions outlined under the GLI or face additional EPA mandates. "We're trying to help utilities anticipate these provisions," says Brocksen. "We're developing analytical tools and generating information and data that will help support efforts to make the provisions as practical and achievable as possible."

The second recent trend is the willingness of EPA and even state regulators to consider risk-based and cost-benefit criteria and to allow their use in discharge permit filings. "The EPA now has a 'talk to me' policy for permit holders and applicants that is very different from the command-and-control, by-the-book approach of the past," says Brocksen. "If utilities can propose acceptable tools and methodologies for risk assessment, the regulators are willing to listen and work with them to reach solutions. The door is still open for good science and logical arguments."

Critical areas of utility concern

If the past is prologue, there is good reason to expect that many of the GLI's proposed revisions to water quality rules for the Great Lakes region could find their way into legislation next year to revise the Clean Water Act's national water quality standards. According to Winston Chow, EPRI target manager for pollution prevention and waste and water management, the Joint Commission on Great Lakes Water Quality took the lead in the 1970s in identifying and setting threshold concentrations for some 56 priority pollutants, including chlorine. These were later adopted on the federal level by the EPA, and still later the list was expanded to 126 pollutants. The commission's concerns about chlorine led to a reduction by the EPA of allowable utility residual chlorine discharge concentrations to 0.2 milligram per liter (for a maximum of 2 hours per day) under the last major revision of the Clean Water Act, in

Issue	Utility Concerns	EPRI Responses
Water toxics	Plant discharges and distributions	PISCES database and model
	Pollutant measurement and analysis	Methods qualification studies
	Discharge limits at or below detection levels	New definitions for compliance monitoring (with Utility Water Act Group)
	Focus on selected metals, metalloids, and bioaccumulative chemicals in downstream sediments	Metals speciation methods Chemical and biological translators General Toxicity Model CompMech models Trace metals control strategies
	Uncertainty of control technology performance	PISCES field test data Technology evaluations
	Integrated watershed risk assessment	RIVRISK model
Intake fish protection	Effects of new design requirements for fish protection on plant operations and fish populations	Intake structure performance database Fish protection system studies CompMech model: fish populations
Thermal discharge	Assessment of impact on downstream biodiversity	Thermal discharge database
	Potential requirements for new plant cooling towers and other cooling options	CompMech model: thermal conditions

KEY REGULATORY ISSUES **Several key issues and areas of concern to electric utilities are emerging in proposed revisions to the Clean Water Act and related regulatory initiatives to tighten standards for protecting water quality. EPRI has important R&D programs in place and information products in development that can help utilities respond to the evolving changes.**

New York State Electric & Gas Corporation's coal-fired Kintigh plant on Lake Ontario

GREAT LAKES INITIATIVE: IMPETUS FOR CHANGE

Much of the momentum for revising the federal Clean Water Act comes from changes already being adopted regionally under what is widely known as the Great Lakes Initiative (GLI). The initiative is the product of the International Joint Commission on Great Lakes Water Quality, an advisory commission established by treaty between the United States and Canada and composed of representatives of the eight states and two provinces that ring North America's largest freshwater ecosystem. Among other proposed water regulatory changes, the GLI has set the framework for adopting zero aqueous discharge limits for toxic substances that are biologically or environmentally accumulative and for some metals species.

1986. Allowable concentrations of selected heavy metals species—such as iron, copper, chromium, and zinc—in aqueous discharges were also reduced at that time.

Now the joint commission is proposing to effectively ban the use of chlorine with a zero-discharge limit. The utility industry has searched extensively for several years for an acceptable and cost-effective substitute biocide, but so far without success. The unavailability of chlorine for use in controlling biofouling in power plant intake pipes could pose substantial technical difficulties and extra costs for utilities.

A zero-discharge target for chlorine is only one of many issues that could translate into major new capital and operating costs for utilities. Another involves so-called intake credits for the existing levels of chemicals in water withdrawals. In a break with past practice, these credits will apply only under limited circumstances and criteria. "This means that if a utility withdraws water already containing 9 parts per million of copper and the standard is 1 ppm," says Brocksen, "the utility has to treat the water and reduce the copper level to meet the standard prior to discharge."

The GLI's use of bioaccumulation factors to derive human health and wildlife criteria—criteria that are encompassed by the integrated watershed management approach—can lead to very restrictive contaminant limits for chlorine, for heavy metals like mercury, and for organic compounds like polycyclic aromatic hydrocarbons. Moreover, the use of defined mixing zones in which discharges are allowed to exceed limits briefly before dilution is on the way out. For all bioaccumulative contaminants of concern, there will be an immediate prohibition on the use of mixing zones for all new discharges; the use of zones for existing discharges will be prohibited after 10 years.

PAM FRANCIS/LARSON INTERNATIONAL

Chicago and Lake Michigan

The GLI proposes three tiers of water quality and antidegradation criteria, with different time frames for implementation and compliance. This approach will result in the listing of more chemicals, and the criteria for listing will be based to a greater degree on limited data and the application of safety factors. "In other words, under the GLI, state regulators can choose to be very conservative and are not necessarily going to base criteria on any new science," Brocksen explains.

An ability to meet a standard implies a

capability of measurement at that level. The GLI's guidance for mercury is one billionth of a gram per liter, which experts say is near or below the limit of detection. At EPRI, Chow and his group are working to identify more-practical detection limits for regulatory filings and decision making.

Also, wildlife water quality is becoming a key factor in deriving water quality guidance, which could lead to a further lowering of discharge limits to protect particular threatened species. "They're moving further up the food chain in establishing water quality standards," says Chow. "Previously, aquatic life was of primary concern, but now included are animals that feed on aquatic life—migratory birds, for example—so the ramifications are far-reaching, literally."

The GLI proposes to set standards for allowable concentrations of bioaccumulative chemicals in lake bottom sediments and banks far downstream from discharge sources. Brocksen's group is working to better understand this aspect and to generate data that can support a case for reasonable regulation. "In the case of chlorine, for example, the bioaccumulative compounds of concern have not been detected in receiving water bodies at levels that are perceived to be a threat," points out Brocksen. His and Chow's groups plan to work together to obtain sediment samples from plant water systems, plant discharges, and points downstream for the purpose of conducting parallel field and laboratory ecological studies. These studies will assess the bioaccumulative risks of chemicals in sediments.

The GLI has also called on the U.S. and Canadian governments to develop research strategies for addressing the air deposition of toxic substances in the Great Lakes Basin and to expand the definition of persistent toxics to include radioactive pollutant species emitted by coal-fired power plants.

The potential cost of GLI compliance to utilities in the Great Lakes Basin was studied by ENSR Consultants in 1993. The analysts estimated costs for all the initiative's tighter standards under a worst-case scenario and tallied the results. For waste streams other than noncontact cooling water, GLI compliance could involve as much as $1.4 billion in capital costs and $200 million a year in additional operating and maintenance costs. For converting once-through cooling systems to cooling towers and treating the blowdown before discharge, capital costs could run as high as $13 billion, with an extra $890 million a year in O&M costs. The estimates include potentially higher regulatory compliance costs for nuclear as well as fossil plants in the region.

A proactive EPRI response

As with previous environmental regulatory initiatives with potentially major cost implications for the electric utility industry, EPRI is mounting a broad, multitargeted R&D response to the evolving tougher clean water rules. The response integrates efforts by two EPRI groups. Work in the Generation Group focuses on detecting, measuring, and characterizing chemical discharges in power plant aqueous waste streams and on the evaluation and engineering of control technologies. Work in the Environment Group focuses on developing predictive analytical models that relate utility chemical discharges with downstream water quality levels, project the ultimate environmental fate of the discharged substances, and assess ecosystem impacts. The groups will gather the data and produce the analytical tools utilities will need to navigate the expected murky, choppy waters of the Clean Water Act revisions and, eventually, to develop site-specific compliance plans.

Beyond water toxics, the GLI's integrated watershed management approach is also likely to be reflected in rewrites of the Clean Water Act sections that relate to thermal discharge limits and to fish protection at power plant cooling intake structures. Significant new requirements in either of these areas could have major capital and operating cost implications for utilities.

"It is imperative that EPRI's work precede the enactment of the various clean water statute revisions so that electric utilities can be proactive in responding as legislation takes shape," says Chow. "Our R&D results will help utilities get ahead of the curve this time around, unlike the case with some earlier rewrites of environmental rules.

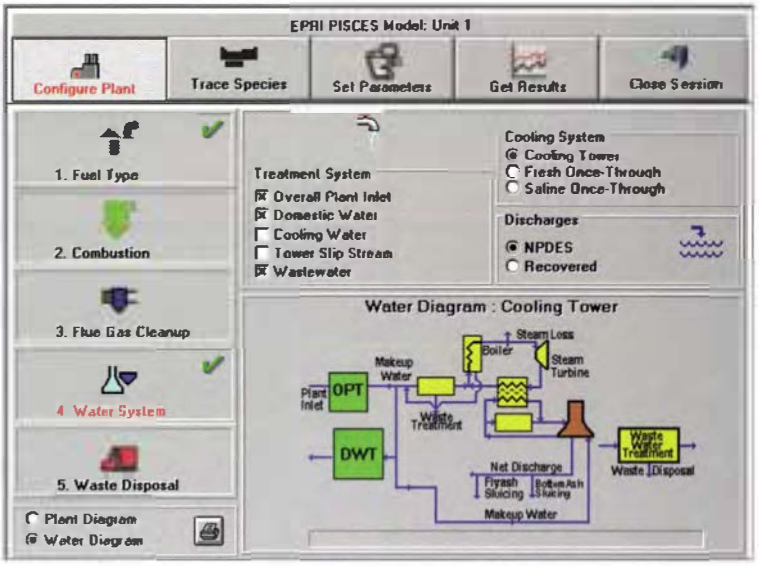
"We're working hard to ensure that utilities can have confidence that the data and tools we are developing will be applicable to specific sites and will provide means of extrapolating and interpreting discharge and other data in strategically meaningful, scientifically supportable ways. In part, that means we are using data-gathering methods that will ensure there will be no argument over how the data were collected, only perhaps disagreements about their interpretation. This was not always the case in the debates about acid rain or PCBs and dioxins."

Additional measurements to quantify and characterize power plant aqueous waste streams are planned this fall under EPRI's PISCES (Power Plant Integrated Systems: Chemical Emissions Studies) program. These plant discharge measurements will supplement an existing 180,000-record PISCES database, nearly one-third of which relates to aqueous waste streams. The new data will fill key gaps in knowledge about the sources, concentrations, amounts, and particular species of chemicals emitted by utilities in aqueous waste streams, including cooling water discharge, ash ponds, and storm runoff. Related work will qualify applicable sampling and analytical methods.

Such information will enable the PISCES power plant chemical assessment model to predict the pathways of trace chemicals in power plant process streams and to estimate discharge amounts. These results will provide utilities with important capabilities for use in reporting aqueous emissions under the Toxic Release Inventory rules, whose exension to electric utilities has recently been proposed. And utilities can use these same tools for developing pollution prevention strategies and environmental benchmarks for plant operations.

Better data on utility aqueous emissions—data with known precision and reliability—will help improve the realism and credibility of chemical and biological trans-

PISCES FILLING KNOWLEDGE GAPS Power plant aqueous discharges contain trace amounts of toxic substances like metals, acids, and organic compounds, and stricter proposed regulatory limits will increase the need to understand the behavior, environmental transformation and transport, and ultimate fate of such substances in greater detail. EPRI's PISCES project is filling key knowledge gaps by characterizing toxic species in fossil plant process and waste streams. Since its inception in 1988, PISCES has amassed an unparalleled body of information about fossil plant chemicals. It is a cornerstone of EPRI's efforts to define the health and environmental risks of such trace discharges as a basis for utility risk management and regulatory compliance.



The PISCES model enables utilities to predict process flows and trace discharge rates from input on plant equipment, fuels, reagents, and makeup water.

EPRI-developed laboratory quality assurance–quality control design guides help utilities exert more control over subcontractor analyses and perform some sampling and analysis in-house.

A 180,000-record relational database lets users explore the correlations between toxics discharges and different fuel and equipment combinations.

PISCES is improving trace metal measurements through the use of rigorous sampling procedures, cleaner reagents, and more-sensitive analytical equipment.

lator methodologies being developed under Brocksen's program. As their names imply, the methodologies can be used respectively to translate discharge concentrations into downstream water concentrations and to translate chemical concentrations downstream into biological impacts on aquatic life.

Bioassays and animal toxicological studies yield the dose-response data that provide the critical link between environmental concentrations of chemicals of interest and balanced assessments of the risks of aqueous chemical discharges to fish populations, other aquatic life, and other animals in a watershed, as well as to human health. EPRI has produced a number of specific models for such risk assessments and is developing others that will provide critical information for evaluating the overall economic costs and benefits of alternative management strategies and control technologies.

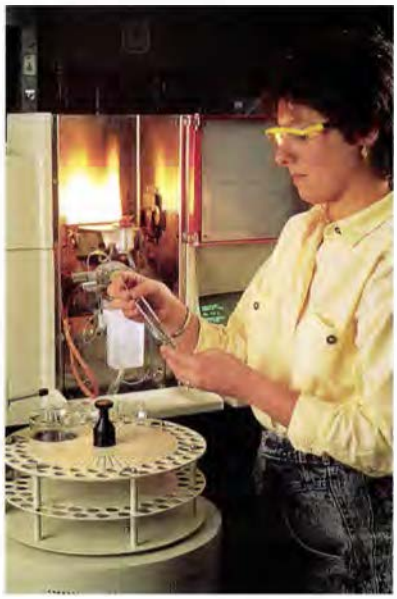
EPRI is planning the second annual International Clean Water Conference for March 25–27, 1997, in Baltimore, at which progress and early results of the Institute's R&D response to anticipated changes in water quality regulations will be presented. Hosted by Baltimore Gas and Electric Company and cosponsored by various national and international organizations, the conference will stress the need for defensible scientific studies as the basis for water quality regulation and new technology, both in this country and abroad.

Opportunity for risk-based assessment

The underlying value to utilities of the results of EPRI's multielement R&D response is not that they will fend off significant revisions to clean water legislation. If the GLI is indeed a presage, the statute revisions may well contain provisions that are not supported by solid environmental data or science, Brocksen warns. But it will be in the regulatory review and analysis of compliance plans in permit filings that utilities may hope to find an openness to rational trade-offs among risks, costs, and benefits.

"In the past, the EPA regulated primarily on the basis of best available control technology," says Chow, "but now it's more willing to acknowledge that risk assessment methods have come a long way over the years. The agency seems to agree that we can increasingly rely on these risk models to give us perspective on the likelihood of specific events so that we can better understand their consequences."

In fact, the EPA recently acknowledged the validity of EPRI's risk assessment approach to the development of a chemical translator for aqueous emissions, which was, in effect, an improved version of an earlier approach published by the EPA. "We took what they had and produced a readable, useful risk assessment tool for chemical translation for utilities," says Brocksen. "Now, in an unprecedented development, the EPA has decided to join EPRI and the Utility Water Act Group in jointly publishing our improved, accepted methodology."



HELPING UTILITIES DEMONSTRATE COMPLIANCE From extensive interlaboratory validation studies, EPRI developed revised definitions for compliance monitoring detection levels and quantitation levels for trace metals. These definitions reduce the risk of false-positive measurements and resulting discharge permit violations, which can cost as much as $25,000 a day in regulatory penalties. The projected value of avoided penalties to EPRI members of the Utility Water Act Group over the next decade is $52 million.

Both the House and Senate versions of legislation revising the Clean Water Act incorporate the use of risk assessment methodology in which costs as well as benefits are considered. The principal point of contention has been the threshold dollar cost at which projects would require risk-based assessment.

"I think that in many cases our utility members are ahead of the curve in water quality regulation as a result of the work that has already been done in terms of both emissions discharge data and ecological assessments," says Brocksen. "If the revised Clean Water Act does allow for risk-based assessment, then we have many tools that can help utilities. We still need to generate additional information in order to make the assessments more realistic or robust for a given issue, whether it is of a chemical or a mechanical nature.

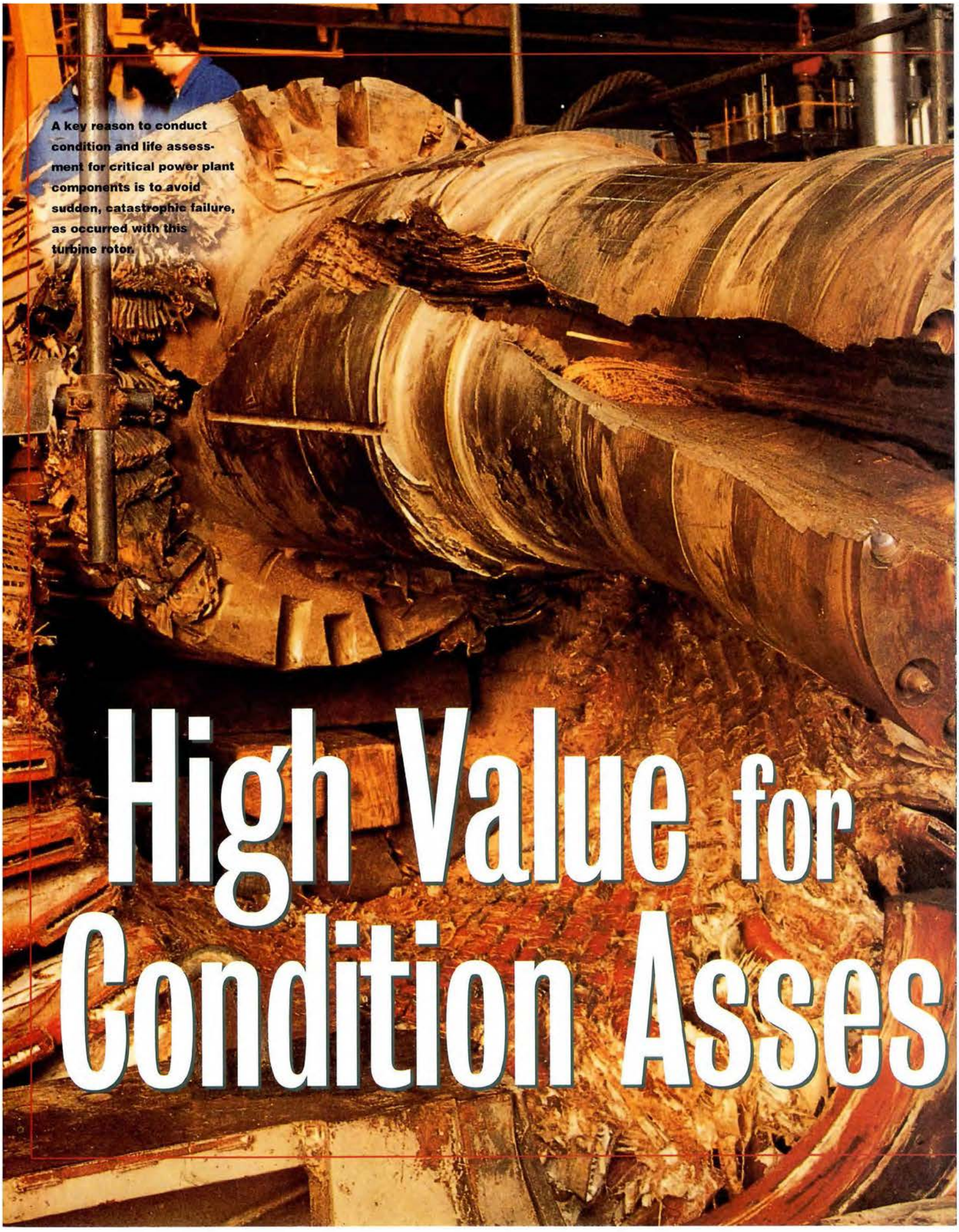
"As the national political debate over revisions to the Clean Water Act comes to a head, it's important to remember there is no evidence at this juncture that electric utility operations cause acute problems for the environment or human health as a result of aqueous discharges. All of the renewed concern is based on assumptions about long-term, chronic exposure to substances eventually coming back into soluble form. The utility industry has an opportunity to make a difference—with good science and defensible measurements—in the way things ultimately work out.

"Clearly, there is strong public support for maintaining the nation's water quality and preventing deterioration that could threaten aquatic life, wildlife, or human health," Brocksen concludes. "Our job is to help the utility industry be responsive to the public's expressed desire in a manner that is consistent with good environmental science." ■

Further reading

Clean Water: Factors That Influence Its Availability, Quality, and Use. Edited by Winston Chow, Robert W. Brocksen, and Joe Wisniewski. Dordrecht, Netherlands: Kluwer Academic Publishers, 1996.

Background information for this article was provided by Robert Brocksen of the Environment Group and Winston Chow of the Generation Group.



A key reason to conduct condition and life assessment for critical power plant components is to avoid sudden, catastrophic failure, as occurred with this turbine rotor.

High Value for Condition Asses

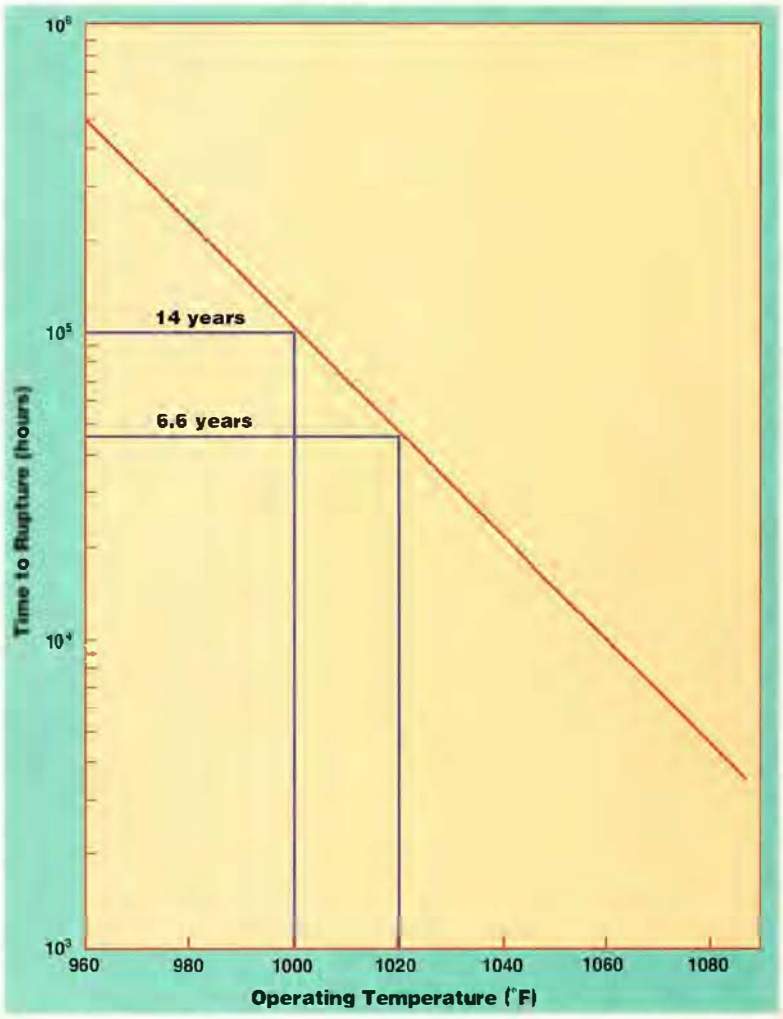
sment

THE STORY IN BRIEF Assessing the condition and remaining life of high-temperature power plant components can help a utility optimize inspection and maintenance schedules, make replacement decisions, and avoid premature equipment failure. Recent advances in this field make it possible to operate some power plants well beyond their nominal design life, with tremendous potential savings. The first step in conducting life assessment is to determine the present condition of a component. EPRI has championed a three-level approach to this task: calculations to screen for potential damage, nondestructive evaluation to detect degradation and cracks, and refined analysis based on destructive testing. In thin-section components, rupture results from uniform, bulk damage. In heavy-section components, on the other hand, failure results from cracking in localized regions of stress concentration. For components that are brittle and either highly stressed or subject to high cycle fatigue, crack initiation essentially signals the end of life. However, for components that are stationary or made from highly ductile steels, crack propagation can be tolerated up to some critical level, and periodic inspections can help keep the component in service. Research on advanced methods for assessing material condition nondestructively and more accurately is continuing.

by John Douglas

By the year 2000, nearly 70% of U.S. fossil plants (43% of the nation's fossil generation capacity) will be more than 30 years old, and many critical components will be approaching the end of their nominal design life. At the same time, utilities are finding it economically attractive to extend the use of these plants for several more years, often under the more severe operating conditions associated with cycling duty. In anticipation of these trends, EPRI initiated a wide-ranging program of research nearly 10 years ago to develop new techniques for assessing the actual remaining life of high-temperature power plant components. As a result of this decade-long effort, utilities have been provided with new life assessment tools that can be used not only to extend the viability of older plant components but also to improve the operation and maintenance of new equipment.

Being able to estimate more accurately the remaining useful life of major high-temperature components, such as boilers and turbines, better enables a utility to make decisions about when to repair or replace various pieces of equipment, how often to inspect them, and how to change plant operating conditions in order to avoid premature failure or replacement. In addition to offering such opportunities to contain operating and maintenance costs, life assessment is critical for making plant-level life extension decisions, which have become increasingly important as utilities seek to provide least-cost generation in preparation for a more competitive environment.



EFFECT OF TEMPERATURE **The life expectancy of power plant components may be quite sensitive to changes in operating temperature. For example, at 9.5 ksi stress, a temperature increase of only 20°F can decrease a steam tube's time to rupture from 14 years to less than 7. As a rule of thumb, component life is about halved with each 20° increase in temperature.**

Work managed by EPRI's Strategic R&D staff has improved on condition assessment capabilities by increasing the fundamental understanding of several degradation mechanisms and developing techniques to determine how far degradation has progressed in specific plant components. From this research have come a variety of guidelines, software, and other products developed by several EPRI business groups to support utility decision making about what to do with aging equipment.

"Condition assessment has gained strategic importance in recent years," says Vis Viswanathan, manager for materials application technology, Strategic R&D, and leader of EPRI's Condition and Remaining Life Assessment (CARLA) Support Team (see sidebar). "Because of recent progress in this area, many utilities may be able to realize the economic benefits of operating their plants well past their nominal design life of 30 to 40 years, with accumulated savings in the billions of dollars. Over the past decade, EPRI has emerged as the world leader in life assessment for high-temperature power plant components, not only through its support of pioneering research in this area but also by developing cross-disciplinary expertise that is available to our members through the CARLA Support Team. This expertise brings a very strong value-added component to what we do."

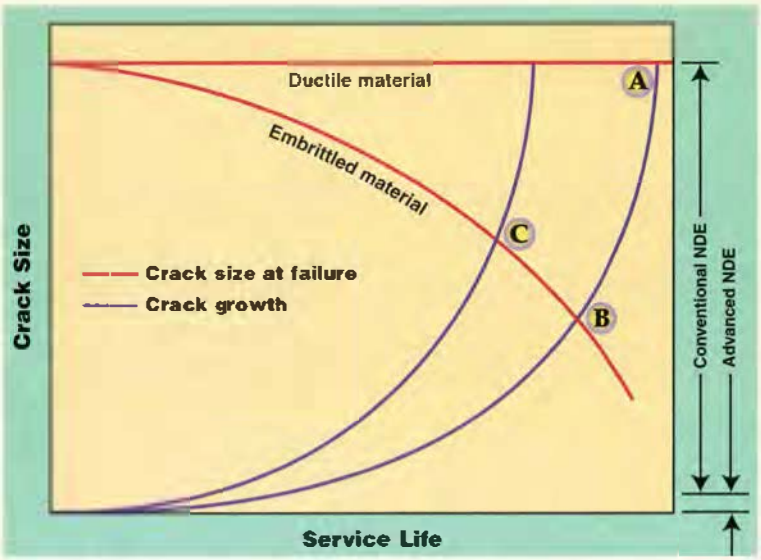
Actual life versus design life

Although the term *design life* is often applied quite loosely to indicate the expected term of service for almost any power plant system, its metallurgical definition is restricted to high-temperature components subject to creep—the progressive, time-dependent deformation and failure that result from prolonged exposure to extremes of heat and stress. In principle, low-temperature metal components, such as water pipes, should last indefinitely. They are generally designed on the basis of simple strength, and the primary failure mechanism of concern is brittle fracture, brought about by excessive pressure or degradation resulting from corrosion.

For components that operate above about 900°F, however, both deformation and fracturing inherently depend on how long the components have been operated under specific conditions of temperature

and pressure. The design stress of these components is usually based on the expectation that they will either rupture or reach an allowable amount of strain in 100,000 hours. When further safety factors and service conditions are considered, this figure translates into an operating life of approximately 30 to 40 years.

The actual life of high-temperature components, however, may be very different from their initially specified design life. A component designed to operate at 1000°F for 40 years, for example, could have its life reduced to only 5.7 years if operated at 1050°F. Other factors that can reduce the life expectancy of components include increased load cycling, corrosion, embrittlement, and unanticipated stresses. Conversely, several factors—such as generous safety margins, relaxation of stresses, good materials properties, and conservative operation—may allow a component to last far longer than its design life.



FAILURE SCENARIOS **A number of factors must be considered in assessing the effect of crack growth on the life of thick-section components. For example, if the metal remains ductile, the component may be able to stay in service for its full design life, despite considerable crack growth (point *A*). On the other hand, much smaller cracks can cause failure in embrittled metal (*B*), allowing less crack growth before a component must be retired. Unanticipated factors like excess cycling, temperature excursions, or corrosion can accelerate crack growth, further shortening service life (*C*). Conventional nondestructive evaluation (NDE) techniques are effective in monitoring the growth of a crack once it appears; the detection of incipient damage requires advanced NDE methods.**

Given these uncertainties, the central problems in assessing the life of high-temperature components are how to determine their present condition, estimate how long they can continue operating reliably and efficiently under given conditions, and evaluate the need for replacement or repair. Life assessment generally requires three kinds of information: the degree of damage that has already occurred, the current rate of damage accumulation, and the amount of damage required to cause failure.

Three-level approach

In order to obtain and analyze the necessary information on high-temperature power plant components, EPRI research has developed a three-level approach to life assessment. According to Barry Dooley, Strategic R&D's manager for boiler and cycle chemistry, "Each level requires more-accurate data and more-rigorous analysis than its predecessor and in turn provides a better estimation of residual life."

First-level assessment employs calculational methods to screen equipment for potential damage. The calculations are based primarily on manufacturers' design specifications and on previous utility operating experience with the type of component in question. To address the numerous inaccuracies inherent in these methods, EPRI researchers have developed ways to check the validity of the damage rules and to correct for degradation factors, such as in-service oxidation and softening.

Nondestructive evaluation (NDE) methods represent the second level of life assessment, providing a compromise between simple, first-level calculations, on the one hand, and detailed analysis and large-specimen testing, on the other. In addition to using standard diagnostic techniques, such as ultrasonics and dye penetrant, for finding and sizing cracks in metal, NDE also relies on the analysis of deformation and of microstructural changes by surface replication and microscopy techniques. Advanced NDE methods like x-ray diffraction, magnetic measurements, positron annihilation, and hardness- and density-based methods are also under investigation. These techniques have greatly improved the ability to detect incipient damage before cracks form.

Third-level assessment involves more-refined stress analysis and crack growth analysis and the determination of actual materials properties through destructive testing. Because such destructive tests generally require the removal of significant samples from operating equipment, they are relatively costly and are used only when other methods do not provide enough information. Research emphasis has been placed on developing ways to miniaturize the specimens required so that their removal is less costly and disruptive.

Failure scenarios

Once the condition of a power plant component has been determined, the expected time to failure must be estimated, primarily in order to schedule future maintenance and inspection activities. In some cases, such as catastrophic fracture or rupture, equipment failure is self-evident; but many times, more-subtle failure criteria must be applied. Ultimately, component replacement is an economic decision, which means that failure must be defined in terms of the inability of key equipment to perform safely, reliably, and cost-effectively.

Clearly, catastrophic failure—such as the bursting of a steam pipe or the breaking loose of a turbine blade—can create intolerable expense, both in terms of worker safety and in terms of an extended plant

outage. Each day of forced outage in a 500-MW power plant may cost as much as $500,000 to $750,000, and the failure of a major plant component can lead to outages as long as a year. Even if catastrophic failure is not at issue, however, a variety of other considerations may lead a utility to decide that a piece of equipment has failed in economic terms.

A traditional, conservative approach has been to replace critical components in a plant after 30 or 40 years, without further supporting evidence of impending failure. In other cases, a component is considered to have failed once the frequency of repairs or the loss of operating efficiency has rendered further operation uneconomical. Increasingly, however, utilities are relying on inspection-based failure criteria or destructive testing to indicate the current damage state of metals in high-temperature components.

In the most common scenario, failure occurs locally at welds and in areas of stress concentration. To assess the significance of observed damage, two primary variations of this failure scenario are generally considered: one in which crack initiation essentially signals the end of life, and another in which crack propagation can be tolerated up to a critical level. Initiation-controlled failure usually applies to components that have low toughness or that are thin, highly stressed, or subject to high cycle fatigue. Examples include boiler tubes, older turbine rotors, turbine blades, and embrittled components. The detection of flaws in such components is tantamount to a finding of failure. Propagation-controlled failure usually applies to components that are relatively thick, such as boiler headers and steam lines, or that are made from highly ductile steels with slow crack growth, such as modern turbine rotors. For components like these, failure assessment calls for both detection and sizing of flaws.

CARLA: Life Assessment Expertise On-Call

Many life assessment methods use technologies from various disciplines, and their application often cuts across traditional utility boundaries. To help bridge these gaps and aid utility members with specific problems, EPRI has established the Condition and Remaining Life Assessment (CARLA) Support Team. To date, the documented savings by individual utilities from CARLA activities exceed $400 million.

The CARLA Support Team brings together EPRI staff members from Strategic R&D and the Generation, Nuclear Power, and Power Delivery Groups to accelerate cross-disciplinary research, coordinate technology transfer, and provide consulting services to utility members. Team members also collaborate with peers around the world to address specific high-priority issues. In one ongoing program, for example, CARLA scientists are working with colleagues at Electricité de France, ENEL of Italy, and Taiwan Power Company to develop advanced weld repair technology for use in both fossil and nuclear plants.

The team conducts some original in-house research; this has included the analysis of failure mechanisms in seam-welded piping and the development of new techniques for evaluating generator retaining rings. It also initiates studies by external contractors—for example, ongoing work to develop advanced NDE technology and to assemble comprehensive failure mechanism databases for common utility materials and components. Mechanisms of degradation in low- and medium-voltage cables have also been a subject of intense CARLA research. Current projects are addressing the development of methods to assess the condition of utility cables, insulators, and motors and to estimate the performance of polymeric materials in utility applications.

As part of their outreach function, team members research and write guidelines prescribing remaining life assessment techniques, serve as internal consultants for project managers in EPRI business groups, and provide rapid-response service to utility members. For example, CARLA and NDE Center staff recently helped a utility evaluate an aging turbine and determine that it could safely continue to operate the turbine, thus avoiding premature replacement. □

Turbine blades

Steam turbine blades suffering from metal fatigue as a result of vibration are an example of a component for which crack initiation is regularly used as the criterion of failure. This degradation may be exacerbated by corrosion, in the case of low-pressure turbines, or by creep and embrittlement, in the case of high- or intermediate-pressure turbines. Such blade failures represent the leading cause of steam turbine unavailability and cost American utilities more than $100 million each year. Equally disturbing is the fact that repeat failures are on the rise, indicating that current repair methods may not be adequate.

Although the general antecedents of failure are well recognized, an EPRI survey revealed that the specific cause of blade failure could not be determined in some 40% of the cases reported. Subsequent research has thus focused on providing the analytical capability not only to predict remaining blade life but also to provide a better understanding of the root causes of failure. The result is the computer program BLADE (Blade Life Algorithm for Dynamic Evaluation), which constructs a dynamic model for a blade group in order to calculate vibration characteristics and local strain responses. On the basis of this simulation, BLADE predicts when cracks will occur in high-stress regions.

"Utility engineers can use BLADE to diagnose the cause of specific blade failures after they occur or to evaluate alternative operating and maintenance procedures to prevent further failures," says Tom McCloskey, manager of steam turbine research in the Generation Group. "It can also be used to develop improved blade configurations and procurement guidelines that can help avoid future problems."

One of the first utilities to apply BLADE was Southern California Edison, which had experienced blade failures in its

low-pressure steam turbines. Using the BLADE analysis, SCE engineers were able to successfully retrofit a harmonic-damping shroud in the utility's turbines, saving an estimated $1.3 million at one generating unit alone. In another application, the Tennessee Valley Authority used BLADE to analyze the potential advantages of replacing conventional stainless steel blades with titanium alloy blades in low-pressure turbines at several fossil plants.

In the case of combustion turbine blades, a life prediction code called REMLIFE has been developed. This was made possible by extensive thermal-mechanical fatigue data and damage rules developed in the course of EPRI research.

Creep cavitation assessment

In boiler headers and steam pipes, creep is a major cause of cracking, with damage most likely to appear in localized brittle regions, such as those near welds. Usually, the first sign of creep damage is the formation of microscopic cavities at grain boundaries of the heat-affected zone near a weld, which eventually coalesce and expand into cracks. The evolution of such creep cavitation can be used to provide an estimate of service life already expended and of the actions required to prevent failure.

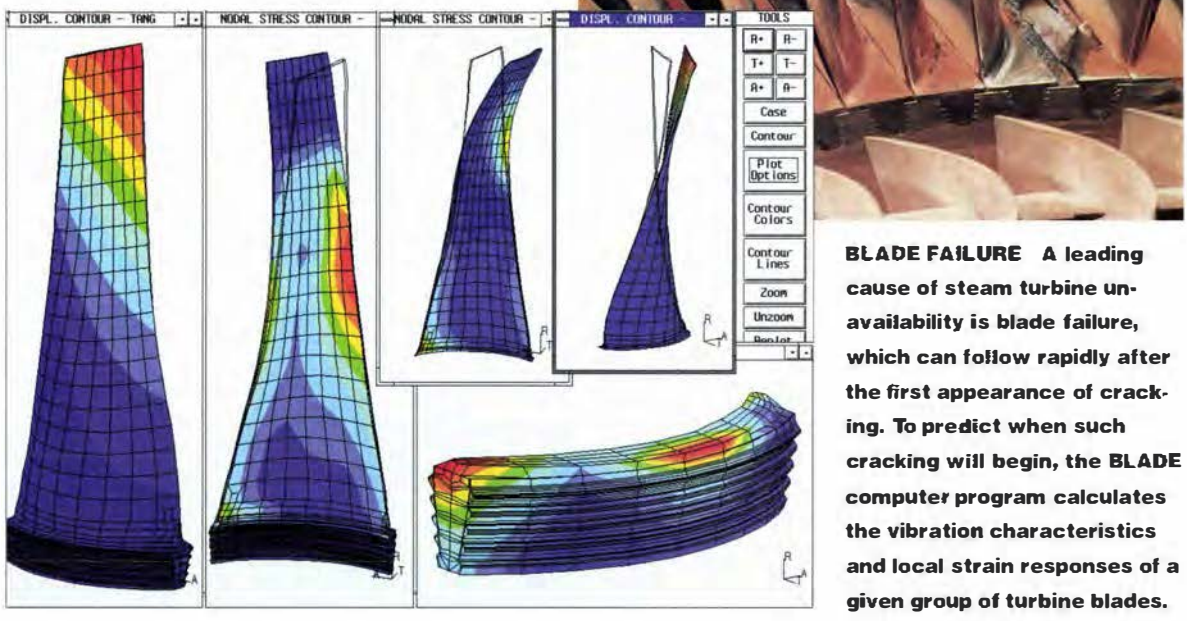
Building on earlier basic research in Germany, EPRI has pioneered the application of an NDE technique to measure creep cavitation by replicating the topography of a metal surface on a plastic film. First the surface is polished and etched; then a softened acetate tape is applied and allowed to dry. Upon removal, the tape faithfully reproduces a negative replica of the metal surface, which can be examined under a scanning electron microscope for signs of cavitation. The procedure is quick, inexpensive, and widely applicable and allows detection of creep damage at a very early stage.

Four classifications of creep cavitation have been identified by means of the surface replication technique: Class A, isolated cavities; Class B, oriented cavities; Class C, microcracks; Class D, macrocracks. These classifications have also been correlated with the expended life fraction for commonly used types of steel, providing a basis for setting inspection intervals.

At the extremes, according to the original approach, Class A damage probably requires no action until the next inspection, while Class D damage probably warrants immediate repair. Establishing a detailed inspection schedule, however, must also take into account quantitative correlations between the extent of cavitation and the creep life consumed. Moreover, the remaining useful life is a function not only of the current cavity classification but also of the duration of prior service. Using a more sophisticated approach developed by EPRI, OG&E Electric Services found that it could conduct 508 fewer annual inspections than originally planned on heat-affected zones of steam pipes in its older plants, for expected savings of $801,000.

Superheater and reheater tubes

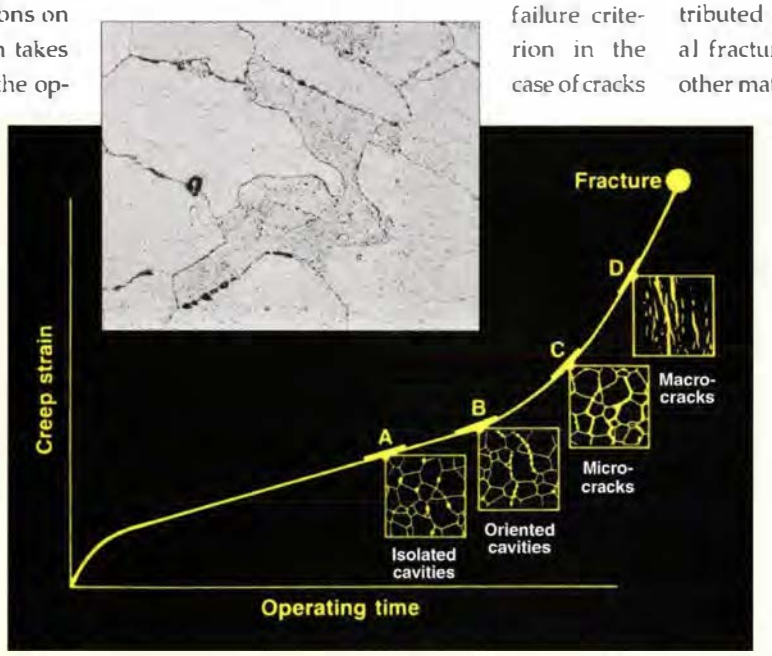
Unanticipated failures of superheater and reheater tubes represent one of the most prevalent causes of forced outages in fossil-fired power plants. Periodic life assessment can substantially reduce such outages. The most common failure mode in these tubes is creep deformation, which can lead to rupture. Traditionally, utilities have used calculational methods to estimate remaining tube life; but to be accurate, the physical models involved require a detailed temperature and pressure history for each tube section in question. Such exposure data are generally not available, given the wide variation in temperature distribution



BLADE FAILURE **A leading cause of steam turbine unavailability is blade failure, which can follow rapidly after the first appearance of cracking. To predict when such cracking will begin, the BLADE computer program calculates the vibration characteristics and local strain responses of a given group of turbine blades.**

across a tube bank, so conservative assumptions are usually made.

EPRI research has addressed the uncertainty in the calculation approach by providing an alternative NDE approach that, in effect, provides an equivalent temperature history for specified locations on a tube wall. This approach takes advantage of the fact that the operating temperature of the tube metal continuously increases during its service life because of steamside scale buildup. The extent of such oxide scaling can easily be measured by using ultrasound inspection or direct sampling. Once this information has been obtained, a utility can use the recently developed computer program TUBELIFE to calculate the amount of creep damage that has accumulated over time and can thus estimate remaining service life. The code incorporates considerable new knowledge regarding oxide growth kinetics, fireside corrosion kinetics, and applicable stress formulations.



CREEP CAVITATION **A leading cause of metal cracking is the time-dependent deformation of a metal at high temperature, a phenomenon known as creep. Such damage is often manifested as cavitation—the formation of microscopic cavities at grain boundaries, which can coalesce into microcracks. This progression can be monitored by using a special acetate tape to take a "fingerprint" of the metal's surface; the surface topology replicated on the tape (photo) can then be examined under a microscope.**

"The process of measuring oxide thickness and using the TUBELIFE code has become the industry standard for managing superheater and reheater component life," says Rich Tilley, manager for boiler life optimization in the Generation Group.

In a typical application of TUBELIFE, Arizona Public Service used the methodology on tubes from a superheater assembly at its Four Corners station. By thus improving its tube maintenance and replacement scheduling and minimizing the need for tube sample removal, the utility estimates that it will avoid having to purchase some 3.5 million MWh of replacement power.

Predicting rotor life

Managing the life of a steam turbine rotor can be particularly tricky: sudden catastrophic failure, in which the rotor literally splits apart during operation, can be spectacularly destructive; however, rotors are so expensive that premature replacement can put a strain on capital reserves. Traditionally, crack initiation was used as the failure criterion in the case of cracks in the rotor bore, but with the emergence of highly ductile clean steels and more-sophisticated analytical capabilities, the application of crack propagation criteria has become more common.

A major EPRI contribution to rotor bore life assessment came with the development of the SAFER (Stress and Fracture Evaluation of Rotors) computer program, now available for use on personal computers. SAFER analysis begins with a preset model of a generic rotor, which is used to assign initial default values. The user then improves on this average rotor profile by entering additional information on a specific rotor. In particular, ultrasonic inspection data can be used to provide important information about flaws and defects in the rotor. EPRI has quantified the uncertainties associated with this type of inspection procedure. SAFER analyzes the data to estimate whether clusters of small flaws are likely to merge and form more-serious defects.

Among other calculations, SAFER determines how stress and temperature are distributed in the rotor. On the basis of metal fracture toughness, crack growth, and other materials properties extensively quantified by EPRI, the program then predicts the number of operating cycles required for flaws to reach a critical size. It also shows the probability of failure at any time in the rotor's remaining life.

In one typical application, Rochester Gas and Electric used SAFER to conduct an independent analysis of a 34-year-old rotor whose manufacturer had recommended immediate retirement after the discovery of numerous small flaws near the bore surface. The SAFER analysis indicated that the rotor could be safely restored to service by enlarging the bore to remove all flaws. By doing so, the utility estimates it realized one-time savings of $1 million. When the SAFER users group conducted a review of other applications of the program by 39 utilities on more than 100 rotors, it estimated aggregate savings of approximately $168 million.

Small-punch testing

The assessment of component fracture proceeds under the assumption that the metal in question has retained its original toughness—that is, its resistance to cracking. If the metal has become embrittled in service, however, its tolerance for cracks is reduced and the critical crack size at which sudden failure occurs may decrease precipitously. Unfortunately, directly measuring the toughness of metal in most heavy-section components, such as turbine rotors and pressure vessels, has required destructive testing of multiple samples. Because removing such samples from in-service equipment is impractical, indirect calculations are generally used to estimate tough-

ness on the basis of very conservative assumptions—the result being small critical crack size predictions, short lifetimes, and frequent inspection requirements. With an increasing need to control maintenance costs, the search for a more accurate, less expensive way to measure toughness has become a high research priority.

The toughness of metal is usually characterized by the parameter fracture toughness, or K_{Ic}—the critical stress intensity at which fracture occurs. This parameter typically varies with temperature: many metals become more brittle, and thus are more likely to crack, under colder conditions. As a result, providing a longer warm-up period for power plant components can help prevent damage.

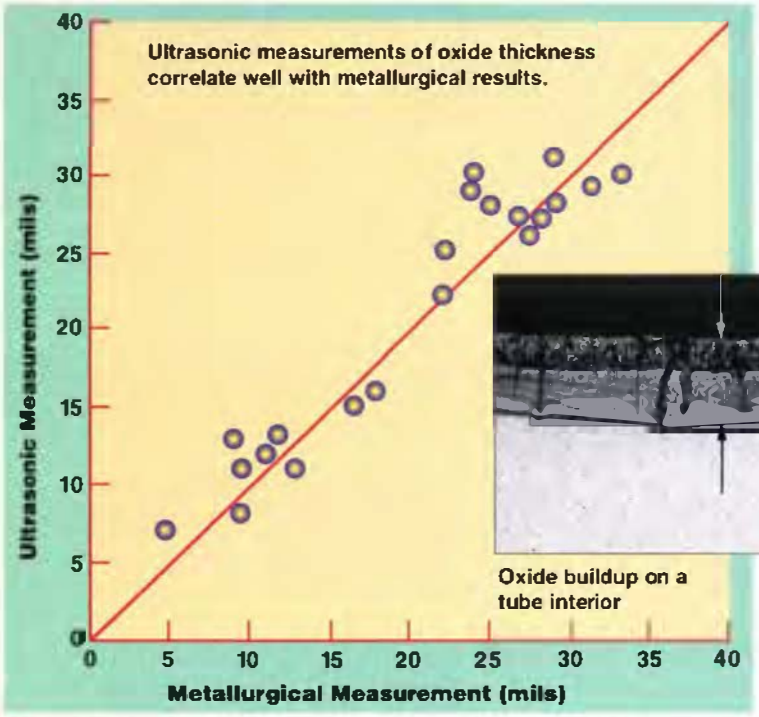
Since measuring the K_{Ic} of in-service equipment directly is seldom practical, the parameter is usually estimated by using its empirical relationship to the temperature at which the fracture behavior of a material changes. This fracture appearance transition temperature (FATT) signifies the point below which a metal becomes brittle and above which it is ductile. Unfortunately, the standard test specimens necessary for measuring FATT are also too large to permit routine sample removal from operating equipment.

A long-term research program sponsored by EPRI has produced several innovative techniques for estimating FATT, including metal etching and chemistry-based calculations. One of the most important new methods is the small-punch test, a direct mechanical test for measuring component material toughness. This method, which is relatively inexpensive and essentially nondestructive to implement, uses a punch-and-die apparatus to test miniature specimens. The specimens are disks with a diameter about half that of a shirt button and a thickness equivalent to a few sheets of paper. Such specimens can be removed nondestructively from component locations that would otherwise be difficult to access. To determine when crack initiation occurs, a video camera with a magnification of about 50× monitors the specimen being tested. The die assembly is contained in an environmental chamber so that temperature can be varied around the FATT point.

In initial small-punch-test experiments, researchers measured the energy required to crack specimens of representative power plant metals and found that the amount of energy differed sharply at various temperatures, depending on whether the metal was in its brittle or ductile state. The small-punch-test transition temperature, in turn, is directly correlated with the FATT of the material—providing a far more convenient way to determine this key parameter and thus estimate K_{Ic}. Following this work, the small-punch test was further enhanced to provide a method of determining K_{Ic} directly and even more accurately, without the need for using FATT as an intermediate parameter.

Utility applications of miniature sample removal and small-punch testing have revealed the overly conservative nature of conventional FATT assessment techniques. In many cases, the improved accuracy has enabled the utilities to avoid unnecessary precautionary measures without increasing the risk of failure.

The first utility demonstration of small-punch testing, for example, involved an analysis of a steam turbine by a midwestern utility considering whether to implement manufacturer-recommended operational changes that would reduce the turbine's cost-effectiveness. The manufacturer indicated that the toughness of the turbine rotor had been compromised, as shown by an estimated near-bore FATT of 218°C. Such a relatively high transition temperature would mean that each time the turbine was started it would operate for an unacceptably long period in its brittle state, increasing the probability of cracking. The manufacturer thus recommended prewarming the turbine before startup and also scheduling more-frequent inspections—both unacceptably expensive measures under the circumstances. When small-punch tests were conducted on four miniature specimens, however, the best-estimate near-bore FATT was found to be only about 77°C, indicating that the proposed operating changes could be relaxed. Furthermore, this reduction in FATT translates to roughly a fourfold increase in tolerable crack size, with comparable in-



CALCULATING TUBE LIFE **The remaining life of superheater and reheater tubes is largely a function of temperature history, which can be calculated with EPRI's TUBELIFE code from the amount of oxide buildup on the inside of the tubes. While oxide thickness can be measured by metallurgical examination of actual tube samples removed from service, ultrasonic techniques have been shown to be an accurate nondestructive substitute. With ultrasonics, oxide data can be taken at many more locations, allowing problem areas to be pinpointed faster and more accurately.**

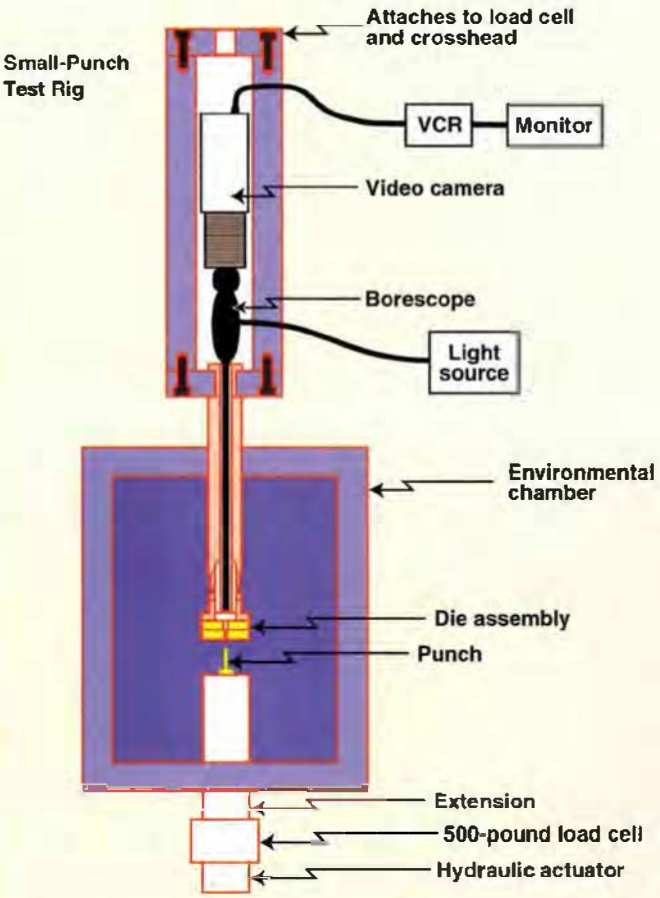
creases in predicted rotor lifetime and in inspection intervals. The direct measurement of K_{Ic} by small-punch testing yields an additional increment in such benefits, which can make the difference between continued safe and economic operation and immediate replacement.

Recently, small-punch tests have also been used to determine the embrittlement of nuclear reactor vessel materials caused by extended exposure to radiation. Without an accurate method of determining K_{Ic} directly, some reactors may have to be prematurely shut down and others may have to be constrained in terms of operational flexibility because of potentially overly conservative assumptions of embrittlement. Experiments have demonstrated the feasibility of small-punch testing for measuring radiation embrittlement, and further research is under way to firmly establish this feasibility through tests on a variety of pressure vessel materials.

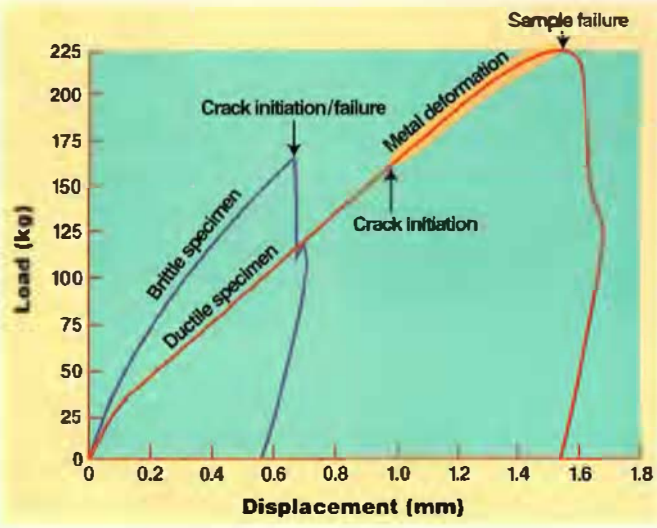
"Results so far have also shown that small-punch tests can be used to determine the effectiveness of thermal annealing to restore toughness in radiation-embrittled reactor vessel steel," says Bob Carter, manager for system and component integrity technologies in the Nuclear Power Group.

Emerging trends

"Advanced life assessment techniques can help utilities reduce operating and maintenance costs significantly by optimizing their operating, inspection, and maintenance procedures and intervals," concludes Vis Viswanathan.



A shallow, 2-cm-diameter metal sample provides three miniature test specimens.



SMALL-PUNCH TESTING An innovative way to measure the toughness of component metal directly is small-punch testing, which requires only miniature samples whose removal is essentially nondestructive to the component. A test specimen is placed in a punch-and-die apparatus, where its displacement is measured as a function of the load. A video monitor determines when cracking begins to occur. As the graph shows, it takes much less energy to cause failure in an embrittled specimen than in a more ductile specimen.

"The techniques can also save on capital costs by preventing premature retirement of key plant components. As a result, we can expect to see more use of on-line monitoring and decision-making tools, coupled with better tracking of plant operating history and improved databases on materials properties. Innovative NDE techniques, such as small-punch testing, will also contribute significantly, as will improved signal processing and new pattern recognition methods. I expect EPRI to remain a world leader in this field as we continue to explore basic materials properties and degradation processes and to use this new understanding to develop even more advanced life assessment tools for utility application." ■

Background information for this article was provided by Vis Viswanathan and Barry Dooley of Strategic R&D, Tom McCloskey and Rich Tilley of the Generation Group, and Bob Carter of the Nuclear Power Group.

CONTRIBUTORS

Technical sources for Journal feature articles

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BROCKSEN

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VISWANATHAN

Preserving Biodiversity: A Delicate Balance (page 6) was written by Leslie Lamarre, *Journal* senior feature writer, with assistance from two members of EPRI's Environment Group.

Jack Mattice, manager for aquatic ecology, came to EPRI in 1981. He previously spent nine years on the research staff of the Environmental Sciences Division of Oak Ridge National Laboratory. He has a BS in biology from the State University of New York at Stony Brook and a PhD in invertebrate zoology from Syracuse University.

Myra Fraser, manager for wildlife and terrestrial ecology, joined EPRI in 1978. Her earlier experience included work as a case management specialist at the Coastside Opportunity Center in Half Moon Bay, California, and as an English teacher in Kyoto, Japan. She received a BA in anthropology from the University of Pittsburgh, an MA in community development from McCormick Seminary, and a BS in biology from the University of Illinois. ■

New Water Regulations on the Horizon (page 18) was written by Taylor Moore, *Journal* senior feature writer, with assistance from two EPRI research managers.

Robert Brocksen is coleader of the Environment Group's target on land and water quality, health and risk assessment. Brocksen first joined EPRI in 1979 as a senior program manager for ecological studies. He left the Institute in 1983 to become the director of the Wyoming Water Research Center and a professor at the University of Wyoming's Department of Zoology and Physiology. He returned to EPRI in 1993. Earlier Brocksen held faculty positions at the University of California at Davis and the University of Tennessee; worked for the National Marine Fisheries Service and for Oak Ridge National Laboratory; and was executive director of Living Lakes, an international surface water remediation demonstration program. He received a BS in fisheries, an MS in fisheries and toxicology, and a PhD in fisheries, physiology, and limnology—all from Oregon State University.

Winston Chow, target leader for pollution prevention and waste and water management in the Generation Group, joined EPRI in 1979. Before that, he was a power plant design engineering supervisor at Bechtel Corporation for seven years. Still earlier, he worked for Raychem Corporation on polymer research and development. Chow holds two degrees in chemical engineering—a BS from the University of California at Berkeley and an MS from San Jose State University—and an MBA from San Francisco State University. ■

High Value for Condition Assessment (page 26) was written by science writer John Douglas with the assistance of **Vis Viswanathan,** Strategic R&D's manager for materials application technology. Viswanathan came to EPRI in 1979, following 14 years with the Westinghouse Electric Corporation R&D Center, where he worked in metallurgical applications and evaluations for nuclear and high-temperature systems. While on a year's leave from Westinghouse, he served as manager and head of metallurgy at the R&D Center for the Indian Heavy Electrical Industry. Viswanathan received a BS degree in chemistry from Madras University and a BE in metallurgy from the Indian Institute of Science. He also holds an ME in metallurgy from the University of Florida and a PhD in the same field from Carnegie Mellon University. ■

Koreans, EPRI Explore EMF Effects on Sheep

EPRI and the Korea Electric Power Research Institute (KEPRI) are collaborating on a two-year animal study in the United States that will help evaluate the possible effects of electric and magnetic fields (EMF) on the immune system. The study, which involves the examination of sheep living under a 500-kV transmission line, is also designed to assess whether any resulting effects are related to the electric fields or to the magnetic fields.

Researchers are studying the immune systems of sheep living under a 500-kV transmission line in Oregon.

South Korea is experiencing a growth in electricity consumption of about 10% annually. In order to meet this increased demand, KEPCO, the republic's only electric utility, will have to double its generation capacity in less than 10 years. Delivering enough power to Seoul, where about 25% of the country's population lives, presents a significant challenge. KEPCO plans to erect two 765-kV transmission lines that will run to Seoul (one from the east coast and one from the west coast), cutting through some populated areas on the way.

The study got under way late last year at a site near Portland, Oregon, with initial support from the Bonneville Power Administration. Earlier, BPA conducted a similar study over a six-month period at the same site. That study concluded that the sheep's exposure to EMF suppressed their immune systems. "We wanted to take a closer look at the questions the previous study raised," explains Kris Ebi, EPRI's manager for the project. "We felt it was necessary to examine the response of the animals' immune systems over a much longer period and to separate the potential effects of electric fields and magnetic fields."

The new study is examining two groups of 15 sheep housed in separate pens under a 500-kV line in BPA's service territory. One of the pens is shielded to significantly reduce electric fields, while the other is not. A third pen, situated away from the line, houses 15 additional sheep that are serving as a control group. Researchers will take blood samples from the sheep and test them in a laboratory to determine how the animals' immune systems respond. Because a sheep's immune system is similar to that of a human being, the study results may offer some indication of the response of the human immune system to EMF.

Other study sponsors are the U.S. Department of Energy and the Western Area Power Administration.

■ *For more information, contact Kris Ebi, (415) 855-2735.*

EPRI-Eskom Project Targets Tuberculosis in South Africa

Tuberculosis, effectively controlled for decades in this country through the use of antibiotics, has made a disturbing comeback in recent years in major U.S. cities. But the problem is far more extreme in developing countries, where the scarcity of effective sanitation has allowed TB to increase to pandemic proportions. Adding to the concern is the emergence of TB strains that are resistant to treatment with antibiotics.

Working with Eskom, South Africa's national electricity supplier, EPRI hopes to demonstrate the effectiveness of a new technology—germicidal ultraviolet light (GUV)—in the battle against the dread disease in that country. This first initiative of a joint venture between the two organizations is being supported by the South African Centre for Essential Community Services (SACECS), officially launched in July by EPRI and Eskom in Johannesburg. The mission of SACECS, modeled after two EPRI community centers already operating in St. Louis and New York, is to demonstrate and transfer appropriate electrotechnologies for improving community health and living standards.

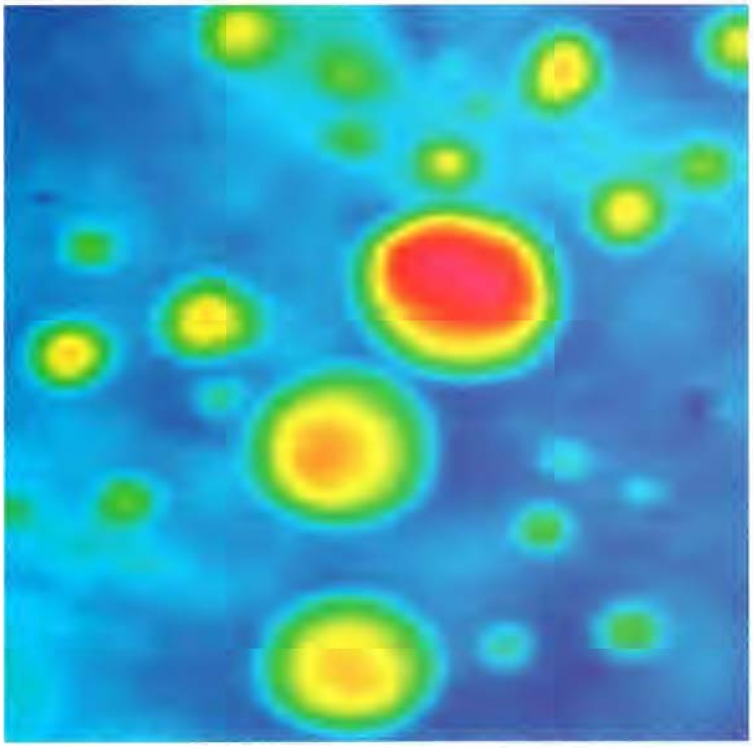
The first step in the SACECS initiative is a pilot program to test the effectiveness of GUV, which kills the mycobacteria that cause TB, at Durban's King George V Hospital, a busy referral center for problematic TB cases. "We are conducting an eight-week double-blind experiment to demonstrate the efficacy of GUV in the hospital's 16 TB wards," says Dr. Philips Onyebujoh, who is in charge of the epidemiological investigation at the hospital. "The technology is being developed in the United States, but we must see how effective it is here as well. TB is a huge problem in South Africa, so this technology has great potential for us. If our pilot program proves GUV's usefulness, the next phase will be to move it into wider deployment."

Dr. Nesri Padayatchi, assistant medical superintendent of King George V, says she is grateful for SACECS's work. "The reinfection of patients with TB or crossinfection with the very dangerous MDR-TB [multidrug-resistant tuberculosis] is a worrying problem, particularly when many patients

are HIV-positive. We have hope that the GUV technology will reduce the number of infectious organisms in the air in our wards, thus reducing the incidence of cross or reinfection."

According to Cynthia Motau, director of SACECS, the GUV project is the first of many planned technology transfers to benefit the people of South Africa and the African continent. "The UV technology has other applications apart from the possibility of combating bacteria in the air. We are getting ready to demonstrate UV as a means of providing clean, potable water for developing communities. This is another of our directions and something we will promote vigorously because the need is so great," says Motau. Other SACECS work envisioned or under way includes programs on ozone water treatment, membrane filtration, waste treatment, and low-cost milk sterilization.

■ *For more information, contact Barbara Klein at EPRI, (415) 855-2413, or Cynthia Motau at SACECS, 27-11-4033425.*



Transient infrared thermography reveals a cluster of disbonding defects in an FGD coating.

PowerGen Demonstrates Infrared Imaging for FGD Coating Inspection

Coatings and linings are commonly used to protect the steel in wet flue gas desulfurization (FGD) systems from corrosion. In a tailored collaboration project with EPRI, PowerGen—a majorelectricity producer in the United Kingdom and one of the Institute's international affiliates—has developed and demonstrated a new technique for quick yet thorough inspection of such coatings, using transient infrared (IR) thermography.

Conventional FGD lining inspections involve a visual survey followed by spark testing, in which thinning and through coating holes are identified with induced electric current. However, spark testing reveals only defects that penetrate the coating; it cannot detect disbondings between the coating and the substrate. Moreover, the misuse of spark testing can actually generate defects in the coating.

In search of a better way to inspect FGD coatings—a nondestructive method capable of surveying relatively large areas quickly to accommodate limited plant outage schedules—PowerGen turned to IR thermography. This technology involves the use of thermal imaging systems to detect hot and cold spots in power plant and other equipment. Passive IR thermography, which generates an image of the thermal energy radiated by a component, is a well-established condition-monitoring tool in utility power plants, but it reveals only surface temperatures, not subsurface details. In active, or transient, thermography, a target object's thermal equilibrium is disturbed by an external heat source, and the flow of heat is observed as equilibrium is restored. Differences in the magnitude and direction of heat flows reveal subsurface defects.

PowerGen has completed extensive thermal modeling to establish heat input requirements and defect detectability. It has also investigated alternative heat application methods for various FGD geometries and coatings.

In field trials at PowerGen's Ratcliffe-on-Soar station, a 2000-MW coal-fired plant near Nottingham, England, transient thermography demonstrated a rapid inspection rate and was able to detect a 1-mm-diameter gas pore in the coating on a gas-to-gas reheater. In another operating plant in the UK, transient thermographic inspection revealed a small area of coating that would have detached with further operation without repair.

PowerGen has also demonstrated transient IR thermography for FGD coating inspection at Pennsylvania Power Company's Bruce Mansfield plant.

Colin Brett, a PowerGen representative, is working as a liaison to U.S. utilities while on loan to EPRI. PowerGen and EPRI can provide interested utilities with additional results and information on this technology application.

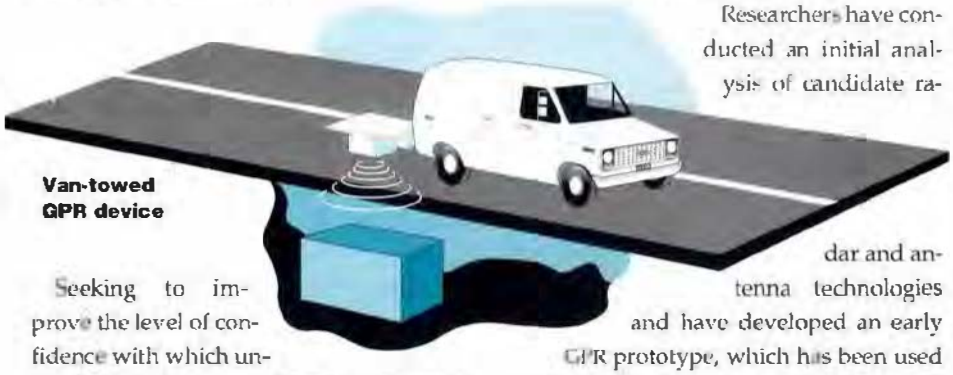
■ *For more information, contact Colin Brett, (415) 855-1081, or Paul Radcliffe, (415) 855-2720.*

Underground Lines

Ground-Penetrating Radar to Save Money, Prevent Accidents

Laying an underground distribution line in an urban area where the earth is already riddled with conduits for water, sewer, natural gas, telephone, cable, and existing electrical services is a difficult task. One wrong move could rupture a gas line or knock out power to hundreds of electric utility customers. Not only do such accidents cost time and money, but they also could risk the lives of utility workers and innocent bystanders.

At this time, electric utilities installing underground lines typically rely on maps that indicate the location of existing subsurface structures. Since such maps are not always current or accurate, however, some utilities also use sensing devices during excavation that help confirm the location of underground structures.



Van-towed GPR device

Seeking to improve the level of confidence with which underground lines can be laid, EPRI has teamed up with the Gas Research Institute to enhance an alternative technology that is expected to be far more reliable—ground-penetrating radar (GPR). A more challenging application of radar technology than traditional uses, GPR must function at short ranges in soils that tend to scatter and weaken radar signals. The technology has been applied to a range of uses, including the detection of land mines and the mapping of tunnels. A key drawback to currently available GPR technology, however, is that it employs a one-dimensional signal-processing technique that makes mapping complex subsurface environments difficult.

In its joint project with the Gas Research Institute, EPRI aims to enhance GPR technology through the development of radar imaging technology. This advancement is expected to involve the deployment of advanced radar techniques and the development of sophisticated processing software that will generate and enhance three-dimensional images. The goal is to create an on-site system that will immediately locate and identify piping, ductwork, vaults, foundations, and other structures that lie as deep as 4 meters underground. "Many accidents can be prevented with improved underground information," says Ralph Bernstein, EPRI's manager for the project. "Both electric and gas utilities will benefit from this technology through accident reduction as well as cost savings in operation and maintenance."

Researchers have conducted an initial analysis of candidate radar and antenna technologies and have developed an early GPR prototype, which has been used to produce images at a test site. EPRI will soon embark on the construction of a precommercialization prototype of the GPR system—an effort that will take about one year to complete. Researchers envision the finished prototype as a two-component system consisting of a van-mounted or -towed GPR device and a lower-cost pushcart GPR device for less accessible sites. The prototype will be field-tested at utility facilities.

■ *For more information, contact Ralph Bernstein, (415) 855-2023.*

Agriculture

New Irrigation System May Reduce Pollutants and Chemical Use

There are 60 million acres of irrigated farmland in the United States. Most of this land is watered by the flood method, in which the irrigation water runs downhill to reach crops. This method contributes to weed growth and soil erosion and can also carry fertilizer and other chemical contaminants into natural underground water sources. Further, the use of tractors to control weed growth—either through mechanical means or through herbicide application—generates fossil fuel emissions and dust that decrease air quality. With farmers coming under fire today both for their use of chemicals and for dust generation, the agricultural community is in dire need of a solution.

As an alternative to the flood method of irrigation, EPRI-sponsored researchers at California State University, Fresno, are testing the use of a subsurface drip irrigation system. The project is part of a broader agricultural initiative at EPRI to improve the efficiency, profitability, and competitiveness of the nation's agricultural sector. "A successful subsurface drip system could help farmers address some of the environmental challenges they face while reducing the total energy used to raise their crops," says Myron Jones, EPRI's manager for the project. "There is a tendency to overlook the importance of agricultural electric utility customers. But productive U.S. farmers provide jobs for regional economies and generate produce that supplies other important utility customers, such as food processors and restaurants. The combined electrical load of all of these food-related enterprises is a significant and important customer base."

Similar in concept to a traditional drip system, which emits water through a hose

snaked along the surface of the ground, the subsurface drip system applies water directly to the roots of the crops that need it. Since the water is applied about 18 inches below ground, weed growth is deterred along with mold and mildew problems. (Weeds typically germinate in water lying on the ground surface.) An herbicide built into the hose protects its emitters from weed intrusion.

In the spring of 1995, the researchers deployed the new subsurface irrigation system on 15 acres of sauvignon blanc grapevines at the university, which is located in the San Joaquin Valley—the country's most productive agricultural region. The system will be evaluated throughout the next two farming seasons, during which researchers will compare subsurface drip irrigation with aboveground drip irrigation. A final report, which will identify the costs and benefits of both types of systems, is expected to be published in 1998.

The subsurface drip irrigation system is directly applicable to other vine and tree crops and could be modified for use with row crops. While the technology is still in its infancy, such systems are being deployed on a small scale in other parts of the country. EPRI's study is expected to greatly accelerate the technology's adoption.

■ *For more information, contact Myron Jones, (415) 855-2993.*

Field Work

EPRI Evaluates Portable Computers for the Utility Industry

The emergence of portable computers has been a boon to the U.S. retail industry, whose workers can scan product prices into electronic memory without as much as a keystroke. This highly visible example shows how just one application of a technology can boost employee productivity daily in a variety of businesses. While portable computers have great potential for use in the electric utility industry, the technology has not been well adapted for such use. EPRI is hoping to change this scenario with the development of hands-free and pen-based computers for utility applications.

Electric utility worker demonstrates a portable computer.

"Not only could such technologies increase productivity, they could enhance worker safety and improve system reliability," says Dominic Maratukulam, EPRI's manager for power systems design. Utility applications that involve data collection and record keeping in the field—applications like inspections, construction tracking, repairs to utility distribution systems, and meter reading—are natural candidates for these technologies.

In a recently initiated project, EPRI is evaluating pen-based and hands-free computer technologies to better meet utility needs. (Pen-based computers enable users to electronically input data—including hand-drawn images—with a pen.) Already, the Institute's researchers have developed a specification for the hardware elements of such computer systems and have identified a dozen candidate systems. One of the candidates is a hands-free system featuring a belt-mounted PC, a hard-hat-mounted display device, and a microphone for issuing voice commands to the computer. A scanning gun allows the worker to identify equipment from a bar code, just as clothing retailers scan in prices from garment tags. This technology would be useful in a variety of utility jobs, from maintaining power lines to completing switching orders at a substation.

After further evaluation, a few of the best candidates will be acquired and field-tested in utility environments. Through the field tests, the computers will be evaluated for ruggedness, portability, reliability, and interface user-friendliness, among other factors. As Maratukulam notes, the machines must be portable and durable enough for line workers to carry up utility poles and easy enough for workers to operate while wearing heavy gloves. He says laptop computers have been problematic for field workers, who have had trouble reading their screens in the glare of sunlight, have had difficulties getting batteries to hold a charge, and have found the computers generally too fragile and awkward to manipulate.

"Once these tests are concluded, we will have some recommendations for utilities as to which of the hardware technologies will be most useful in specific applications," says Maratukulam. EPRI plans follow-up work to develop software programs that will enable these machines to assist in a variety of utility jobs.

■ *For more information, contact Dominic Maratukulam, (415) 855-7974.*

Con Edison Truck Redesign Enables Application of Cable Removal Technique

In 1993, Consolidated Edison Company of New York tried out an EPRI-developed prototype technique for removing jammed underground distribution cable from conduit by vibrating the cable. The ability to replace jammed cable would save Con Edison the expense and difficulty of digging up crowded, busy Manhattan streets to lay new conduit. Typically, the utility spends about $10 million a year for new conduit construction in Manhattan to replace distribution capacity lost as a result of obstructed ducts.

In the test of the prototype, Con Edison successfully cleared 275 feet of tightly jammed cable it had previously been unable to release. The utility was interested in the technique's potential but was concerned about the maneuverability of the equipment, which was housed in an unwieldy trailer pulled by a truck. Unless maneuverability could be improved, the technique appeared to have limited applicability in the New York City area.

To better adapt the cable removal technique to urban use, Con Edison teamed up with EPRI in additional research to develop a flexible, truck-mounted system that eliminates the trailer. Once the prototype truck-mounted system was available, Con Edison used it to remove 1500 feet of stuck cable within a two-week period; later, after further fine-tuning, the company freed another 1200 feet of stuck cable over a six-week period. Cost savings from these initial applications alone were nearly equal to Con Edison's share of the development funding (which was matched by EPRI). And it is estimated that over the next five years, the utility will save more than $2.7 million as a result of quicker repair of feeder problems.

The truck-mounted cable removal system is now routinely used by Con Edison in its Manhattan customer service area on the most difficult cable pulls—those involving 3-inch conduit. "Because it's more maneuverable in the street—a critical concern in New York City—the truck-mounted system lets us efficiently remove jammed cable and respond to feeder problems quickly," comments Con Edison's Leonard Burshtein.

Last year, EPRI's Power Delivery Group awarded three Con Edison staff members—Burshtein, Cliff Garner, and Ralph Mauro—Technology Champion awards for their insight and leadership in the effort to modify the vibration-based cable removal technique to create a tool even more useful in Con Edison's specific operating environment. EPRI has licensed OK Champion Corporation to manufacture the cable removal truck.

■ *For more information, contact OK Champion's Harvey Reed, (916) 587-7381, or Paul Knoerzer, (219) 933-0510, or EPRI's Ralph Samm, (415) 855-2289.*

EMTP Analysis Resolves Live-Line Maintenance Dilemma for PSCo

In an in-house study that saved on consulting fees, Public Service Company of Colorado recently used EPRI's EMTP software to analyze maximum transient overvoltages on an important 345-kV transmission line. Results from the analysis indicated that PSCo could proceed with live-line maintenance, avoiding an outage that would otherwise have been required under a new Occupational Safety and Health Administration (OSHA) standard and that would have jeopardized system stability and overloaded other transmission lines. The utility anticipates further cost savings over the next few years from using EMTP to analyze additional transmission lines.

To demonstrate compliance with the new OSHA standard for minimum safe approach distances for live-line maintenance, PSCo elected to perform an engineering analysis to determine the maximum transient overvoltages (mainly switching surges) on the Craig-Rifle line. Rather than hiring a

consultant to perform the analysis, PSCo's system protection engineering unit saw an opportunity to broaden its experience by performing the EMTP study itself.

After creating the EMTP models and data files, PSCo engineers ran more than 100 cases involving various switching conditions on nearby lines and monitored the resulting transient overvoltage levels on the Craig-Rifle line. According to the EMTP data, the maximum transient overvoltage at any point along the line was well below the maximum allowed under the OSHA standard for live-line maintenance. As a result, the utility's transmission line operations, safety, and engineering departments were able to confidently conclude that live-line work could proceed in compliance with applicable requirements.

PSCo realized nominal savings on consulting fees by performing the EMTP analysis in-house, but the study's primary benefit is the system reliability afforded by not having to take the Craig-Rifle line out of service for maintenance. "The EMTP analysis—backed by EPRI's industrywide credibility—was essential to establishing for OSHA that our safe working clearances are well within their new minimum standards," says PSCo's Renu Arora.

EMTP version 2.1 for mainframe computers, PC workstations, and UNIX workstations is available through the Electric Power Software Center, (800) 763-3772.

■ *For more information, contact Ram Adapa, (415) 855-8988.*

Electric Compressors Move Gas, Stimulate Industry Alliance

In an effort that promises to expand markets for both natural gas and electricity amid deregulation and rising competition in both energy industries, several electric utilities are helping natural gas storage, processing, and transportation companies use electric compressors to move gas along their pipelines. The main driver behind the new interest in electric powered gas compression is that it reduces pollutant emissions.

Natural gas companies have historically used gas-fired internal combustion engines and combustion turbines to drive gas compressors situated at stations along a pipeline. But these units emit nitrogen oxides, which react with organic pollutants to create ozone smog. Without modifications and controls, the units' emissions can exceed limits set by the Clean Air Act Amendments of 1990.

Approached by several member utilities seeking solutions for gas industry customers, EPRI has managed tailored collaboration projects that have pinpointed opportunities for replacing gas compressor engines with electric units and have led to several such installations. One installation effort was conducted with Tenneco Energy of Houston, a major U.S. gas transportation company, which thereby avoided the more expensive alternative of modifying its old engines to meet the new emissions requirements. Another advantage of electrically driven compressors, according to Bill Wickman, Tenneco's manager of business development, is that potential problems in the disposal of lubricating oil and cooling fluids are greatly reduced.

W. Richard Schmeal, director of the EPRI Chemicals & Petroleum Center in Houston, points out several additional benefits of electric compressors. "They are more energy-efficient because variable-frequency drives control the motor speed, enabling motors to maintain high efficiency in a variety of conditions. They can be operated from a remote control station, where the press of a button starts the motor that drives the compressor. Electric compressors are clean and require no ignition or combustion. And unlike their gas-fueled counterparts, they are inherently designed to operate quietly, which is an advantage in urban areas."

EPRI studies indicate that between 1000 and 3000 MW of new demand may be created nationally by electric compression over the next five years. To help both industries understand and apply electric compression technology, EPRI has formed a working group whose program focuses on tools development, education, and market analysis.

■ *For more information, contact Richard Schmeal at the EPRI Chemicals & Petroleum Center in Houston, (713) 963-9307.*

Exploratory Research

Advances in Solid-Oxide Fuel Cells

by Wate Bakker, Strategic R&D, and Art Cohn and Rocky Goldstein, Generation Group

Fuel cells—a clean noncombustion technology for producing electricity from natural gas, light hydrocarbons, or other fossil fuels—are developing as an attractive generation option for utilities. The fundamental technology was invented more than 100 years ago, but until recently fuel cell applications have been limited to space capsules and shuttles. Materials advances by EPRI-funded researchers have been key to the emergence of the technology as a practical option for the power industry.

Space-age technology

Fuel cells use electrochemical processes, mediated by electrolytes, to produce electricity from light fossil fuels. They thus function like batteries that don't run down. Fuel cells remained a laboratory curiosity until the 1960s, when alkaline-electrolyte cells began to be employed in early space capsules as a source of onboard electric power. Since then, fuel cells have become the primary means of generating electricity in manned spacecraft. They power computers, communications devices, heating and lighting systems, and other critical equipment.

Unique characteristics make fuel cells ideal for unforgiving space applications. They are efficient, modular, and, because they have almost no moving parts, highly reliable. Performance is independent of system size. In addition, operation is quiet, emissions are low, and the only by-products are carbon dioxide and water pure enough for drinking.

Properties like high efficiency and low emissions make fuel cell technology attractive to the electric power industry as well, particularly as a distributed generation (DG) resource. DG, which involves situating small, unobtrusive generation facilities close to end users, is being pursued by power producers in response to competition and environmental regulation. It promises to help utilities cut capital outlays, minimize transmission and distribution requirements, increase customer satisfaction, and build new partnerships with customers.

New generations of fuel cells

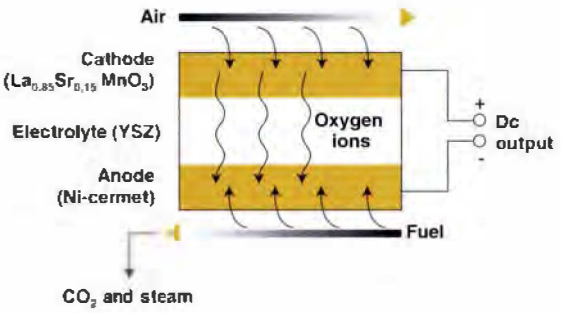
To promote fuel cells as a practical advanced generation technology, EPRI R&D and demonstration efforts have been supporting the development of utility-scale fuel cells for DG, central-station, and repowering applications. With EPRI assistance, megawatt-sized liquid-electrolyte units—phosphoric acid fuel cells (PAFCs)—began entering service in the late 1980s. PAFCs are costly to build and operate, however, and have proved cost-effective only for specialty applications—for example, in areas with severe siting or emissions restrictions. Another liquid-electrolyte type, molten carbonate fuel cells (MCFCs), is in full-scale demonstration, but costs will probably limit this technology to relatively large units (1 MWe or more), thereby precluding it from being used in many DG applications.

The next generation of fuel cell technology, solid-oxide fuel cells (SOFCs), holds promise for economic competitiveness with conventional generation alternatives. This technology, currently being developed by EPRI, makes use of solid ceramic electrolytes of yttria-stabilized zirconia (YSZ) instead of corrosive liquid electrolytes. SOFCs are simpler and more robust than liquid-electrolyte fuel cells, have potentially low manufacturing costs, and offer operational advantages. For instance, PAFCs require costly external fuel processing; SOFCs function at temperatures sufficiently high to reform fuel internally and utilize natural gas directly. Also, there is no theoretical limit on the service life of SOFCs, and they are expected to last considerably longer than PAFCs and MCFCs.

Another advantage is that SOFCs can operate at pressures and temperatures compatible with those of the internal flows of gas turbines, raising the prospect of cy-

ABSTRACT *Fuel cells, which work like batteries but don't run down, are emerging as an attractive power source for next-century utility applications such as distributed generation. However, the economic potential of the most advanced and promising example of this technology, solid-oxide fuel cells (SOFCs), has been limited by materials problems associated with high operating temperatures. In EPRI exploratory research, three new solid-oxide designs are being tested that combine reduced-temperature operation with performance equaling or exceeding that of high-temperature cells. Also being explored are novel SOFC-turbine combined-cycle units that promise an overall efficiency exceeding 75%.*

Figure 1 Fuel cells operate like batteries that don't run down, converting natural gas fuel and air into electricity via electrochemical processes. These processes are mediated by an electrolyte, which allows the migration of ions but blocks the transfer of electrons. Designs with a solid-oxide ceramic electrolyte, like the cell shown here, are simpler and more robust than liquid-electrolyte types and can have an electrical efficiency as high as 60%.



cle combinations that could substantially increase unit performance and cost-effectiveness. For example, operating an SOFC stack at about 15 atmospheres and feeding unconsumed fuel and generated heat to a matched bottoming-cycle gas turbine could result in combined-cycle units with unprecedented efficiency. EPRI computer models estimate a combined electrical efficiency exceeding 75% for SOFC–gas turbine units. Unit size could range down to about 100 kW, although larger, multimegawatt sizes would not be precluded.

The low-temperature challenge

Pilot-scale SOFCs are now being demonstrated by EPRI and others, but they do not fully realize the economic promise of the technology. Capital and operating and maintenance costs remain high because the cells function at about 1000°C and hence must be constructed of high-temperature superalloy and exotic ceramic components. Not only are these costly, but the differential thermal expansion of the materials at extreme temperatures contributes significantly to gas leakage, cracking, and other O&M problems.

To lower costs, SOFC operating temperatures need to be reduced. Optimal would be a temperature between 650°C and 800°C—high enough for internal fuel reforming (which would allow the direct use of natural gas) but low enough to substantially cut capital and O&M costs. At 800°C or below, conventional stainless steels instead of specialty materials could be employed as construction materials and cell interconnectors. And differential thermal expansion would be lessened, reducing O&M problems and extending practical cell life.

The primary research challenge is to achieve high cell performance at lower operating temperatures. As shown in Figure 1, the generation of electricity in SOFCs is based on the flow of negative oxygen ions from a cathode (which is exposed to air) to an anode (which is bathed in hydrocarbon fuel). At the anode, the migrant oxygen ions combine with hydrogen and carbon monoxide to produce water and carbon dioxide. These reactions also generate electrons—electricity. An electrolyte facilitates the transfer of oxygen ions while blocking the flow of electrons between the electrodes.

The amount of electricity produced and the temperature at which the generating efficiency is highest depend strongly on the ability of the electrolyte to conduct oxygen ions; conventional YSZ electrolytes perform best at about 1000°C. At lower temperatures, the ionic resistance of YSZ increases, reducing cell performance to uneconomical levels. New SOFC designs or alternative electrolytes are needed to overcome this difficulty.

Advanced SOFCs

EPRI is directing a suite of exploratory research projects aimed at decreasing the temperature of SOFC operation. Research began in the late 1980s with the study of very thin electrolytes, alternative electrolyte materials, and innovative designs. Current efforts focus on establishing proof of concept for the most promising SOFC technologies revealed in the earlier research. In addition, EPRI is exploring design optimization for SOFC-based combined-cycle units.

Thin-film electrolytes Reducing the thickness of the electrolyte is the most direct approach to maintaining SOFC performance at lower operating temperatures. If the oxygen ions have less electrolyte to pass through, a cell's total (ohmic) resistance can be decreased despite the higher ionic resistance per unit of electrolyte at reduced temperatures. This approach allows the continued use of proven YSZ materials.

The primary difficulty with thin YSZ electrolytes is that very thin films—coatings, actually—are needed for good fuel cell performance at 650–800°C. These coatings must be less than 10 μm thick, about one-third the thickness of a human hair. (By contrast, electrolytes for conventional 1000°C SOFCs are about 150 μm thick.) And to prevent short circuits between anode and cathode, the coatings must be dense and smooth and contain no cracks or pinholes.

In exploratory research at Lawrence Berkeley National Laboratory (RP8062-10) and the University of Utah (RP8062-6), an inexpensive, scalable process has recently been developed for the production of high-quality thin-film YSZ coatings. The new ap-

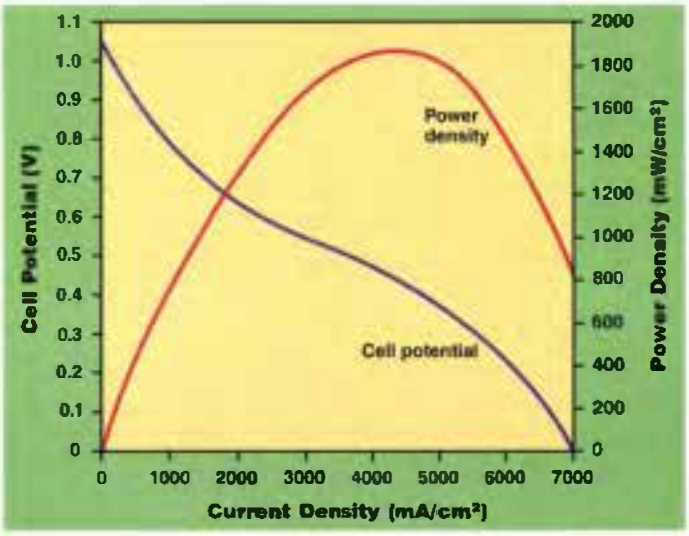


Figure 2 Laboratory test data on the performance of thin-film YSZ solid-oxide fuel cells at 800°C. The maximum power output is 1800 mW/cm². In contrast, the power density of conventional SOFCs ranges from 300 to 700 mW/cm² at 900–1000°C.

proach, adapted from simple chemical methods, makes use of colloidal slurry coating techniques to produce dense films 4–10 μm thick in a single step. The trick is to select and tailor the underlying electrode material (Ni-cermet) to match the shrinkage characteristics of the electrolyte coating during firing.

In laboratory-scale tests, SOFCs with very thin electrolytes produced by using the inexpensive slurry method have operated at about 700–800°C with excellent performance. They exhibited the theoretical maximum for open-circuit voltage, demonstrating that the thin-film electrolyte did not contain defects (pinholes and cracks). Power density far exceeded that of conventional SOFCs at 1000°C (Figure 2), and long-term stability was good (no coating degradation was detected after 300 hours of operational testing).

Ceria electrolytes Alternative electrolyte materials with improved ionic conductivity offer another approach to developing practical low-temperature SOFCs. One possible alternative material is modified ceria (CeO_2). This material was previously found to possess higher ionic conductivity than YSZ. At 750°C, for example, the conductivity of ceria is about the same as that of YSZ at 900–1000°C.

The use of ceria as an SOFC electrolyte presents significant challenges, however. The chief one is that ceria undergoes partial chemical reduction when exposed to the environment at fuel cell anodes. This degradation of the electrolyte results in the development of a small electronic conductivity between the anode and the cathode, lowering the cell's open-circuit voltage and decreasing performance.

In EPRI work at Ceramatec in Salt Lake City, progress has been made in overcoming this problem (RP8062-4). Ceria electrolytes have been doped with samarium to improve their stability in fuel cell environments and reduce the electronic conductivity. In laboratory tests of the new electrolytes, single cells have operated for more than 10,000 hours at 700–800°C without significant loss of performance. The maximum power density of these cells, 300–400 mW/cm^2, is comparable to the performance of conventional YSZ SOFCs at 900–1000°C.

Single-component SOFCs Single-component SOFCs are yet another promising approach to high efficiency at low operating temperatures. Such a fuel cell would consist of a conventional 150-μm-thick YSZ-based electrolyte that has been chemically treated, or "painted," on opposite sides to give it anode- and cathode-like surfaces. Electrical and physical mismatches between electrode and electrolyte materials would thus be eliminated, leading to high efficiency as well as easy construction and long life.

On the basis of materials studies promising excellent performance for single-component SOFCs at 800°C, EPRI has been exploring this concept in research at the University of Pennsylvania (RP8062-9). The most challenging task has been the identification of practical surface-modification processes for converting YSZ electrolyte surfaces into high-quality cathodes. (Anodes pose less of a problem. In conventional SOFCs they are commonly constructed from Ni-cermet, a YSZ-based material; in single-component cells, doping the electrolyte surface with titanium results in similar performance.)

In recent research, the difficulty with cathodes has been overcome: chemical doping with terbium oxides yields a high-quality cathode surface on a YSZ electrolyte. Laboratory tests reveal the performance loss for these advanced cathodes to be less than half that for conventional SOFC cathodes. These results make the single-component configuration a promising design for practical low-temperature SOFCs.

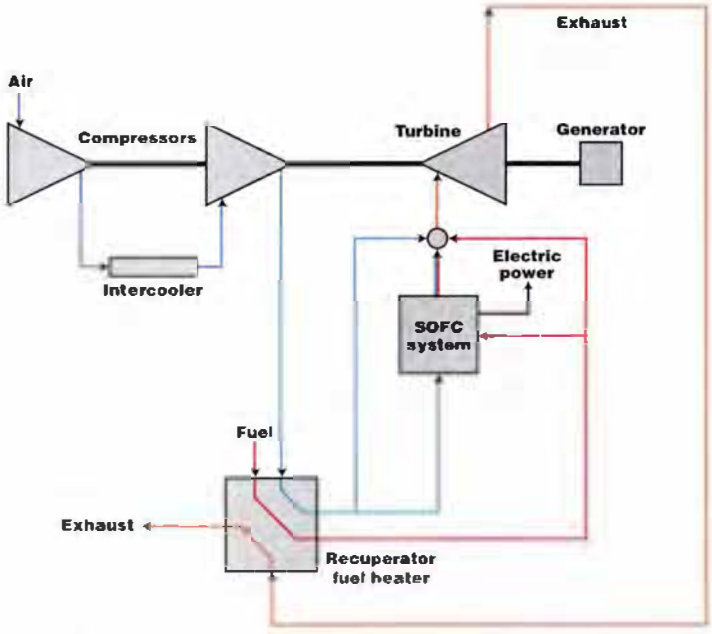


Figure 3 SOFCs may be advantageously combined with a gas turbine by using vitiated air and unconsumed fuel from a pressurized fuel cell to power the turbine. EPRI studies indicate that unprecedented combined electrical efficiency—75% or more—is likely for SOFC–gas turbine combined-cycle units, at costs projected to be competitive with conventional generation options.

Combined-cycle SOFCs The integration of bottoming-cycle turbines with pressurized SOFCs (Figure 3) may offer significant cost and efficiency advantages, and EPRI is researching design optimization to maximize combined-cycle performance (RP4167-1, RP8512-2). To date, computer simulation studies have revealed cycle arrangement modifications that increase the combined electrical efficiency for proposed SOFC–gas turbine units from about 62% to more than 79%. The efficiency gains stem from improved fuel cell cooling and a better match between the SOFC operating requirements and the turbine airflows and temperatures.

Ongoing research

Research progress to date suggests that the successful development of practical low-temperature SOFCs and SOFC-based combined cycles is likely within the next decade. EPRI efforts continue to support the development of these technologies.

To scale up thin-film electrolyte technology, larger cells and small stacks of cells are being fabricated at Lawrence Berkeley National Laboratory and Ceramatec. To explore low-temperature alternatives, a new SOFC configuration is being studied at the

University of Utah. This design employs fine corrugations to increase the contact surface between electrodes and a thick-film YSZ electrolyte, thereby maintaining power density and cell efficiency at reduced operating temperatures. At the same time, the development of ceria cells continues at Ceramatec. Efforts there are concentrating on the construction of small stacks and the optimization of metallic interconnectors; additional research is aimed at improving power density by reducing the thickness of the ceria electrolyte from 250 μm to the 150 μm of conventional YSZ SOFCs. And for single-component SOFCs, a joint demonstration of the technology is being planned by the University of Pennsylvania and Ceramatec.

On the basis of a comparative analysis of the performance and promise of low-temperature SOFCs, EPRI plans to initiate a development program within a year. This program, which may take the form of a consortium including industry and government participants, will focus on the development of a 1-kW low-temperature SOFC prototype. The cell design is expected to incorporate the best features of current efforts. EPRI is also undertaking additional performance optimization studies of SOFC–gas turbine units, and computer modeling is planned to assess the cost-effectiveness of the new combined-cycle designs.

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. EPRI members that fund the business unit issuing a report can receive the report free of charge (or, in the case of bulk orders, for a nominal price). Others should contact the Distribution Center for further information.

Two-page summaries of the reports announced here are available, free of charge, by fax. To receive a summary, call EPRI's Fax on Demand service (800-239-4655) from a touch-tone phone and follow the recorded instructions, using the fax identification number given in the report listing.

CUSTOMER SYSTEMS

Power Electronics Reference Guide
TR-102025 Final Report (RP3088-4)
Contractor: Chester and Schmidt Consultants
Business Unit: Power Quality
EPRI Project Manager: B. Banerjee
Fax ID: 7365

Motor Models and Transient Analysis for High-Temperature, Superconductor-Switch-Based Adjustable-Speed-Drive Applications
TR-102338 Final Report (RP3087-16)
Contractor: University of Tennessee, Knoxville
Business Unit: Power Quality
EPRI Project Manager: B. Banerjee
Fax ID: 7483

Characterization of Compact Fluorescent Lamps and Electronic Ballasts Used in Commercial and Residential Building Systems
TR-104989 Final Report (RP2825-6)
Contractor: EPRI Power Electronics Applications Center
Business Unit: Power Quality
EPRI Project Manager: S. Rector
Fax ID: 23549

Testing of Refrigerant Mixtures in Residential Heat Pumps
TR-105394 (WO3412-6)
Contractor: University of Maryland, Center for Environmental Energy Engineering
Business Unit: Commercial Technologies & Services
EPRI Project Manager: W. Krill
Fax ID: 24216

Power Quality Workbook for Utility and Industrial Applications
TR-105500 Final Report (RP2935-30)
Contractor: Electrotek Concepts, Inc.
Business Unit: Power Quality
EPRI Project Manager: M. Samotyj
Fax ID: 24346

Cold Air Distribution Design Guide
TR-105604 Final Report (RP3280-48)
Contractors: Dorgan Associates, Inc.; EPRI HVAC&R Center, University of Wisconsin, Madison
Business Unit: Commercial Technologies & Services
EPRI Project Managers: M. Khattar, R. Wendland
Fax ID: 24501

Measuring Residential Water Flow: Evaluation of Clamp-On Ultrasonic Flowmeters
TR-105840 Final Report (RP3269-22)
Contractor: GEOMET Technologies, Inc.
Business Unit: Retail Market Tools & Services
EPRI Project Managers: R. Gillman, P. Hummel
Fax ID: 24835

Light Logger Placement Guidelines for Residential Lighting Studies
TR-105842 Final Report (RP3269-23)
Contractor: GEOMET Technologies, Inc.
Business Unit: Retail Market Tools & Services
EPRI Project Managers: R. Gillman, P. Hummel
Fax ID: 24839

Leveraging Limited Data Resources: Developing Residential End-Use Load Shapes Using Transferred Data
TR-105843 Final Report (RP2980)
Contractor: Quantum Consulting, Inc.
Business Unit: Retail Market Tools & Services
EPRI Project Manager: R. Gillman
Fax ID: 24827

Heat Transfer Characteristics of Alternate Refrigerants, Vol. 3: Condenser and Evaporator Outside Tube
TR-106016-V3 Final Report (RP3412-53)
Contractor: Lehigh University
Business Unit: Commercial Technologies & Services
EPRI Project Manager: S. Kondepudi
Fax ID: 25147

Field Testing of Electronically Commutated Motors for Supermarket Display Cases
TR-106075 Final Report (RP3526-9)
Contractor: Foster-Miller, Inc.
Business Unit: Commercial Technologies & Services
EPRI Project Manager: M. Khattar
Fax ID: 25251

ReQuest II: An Investigation of Consumer Attitudes Towards Telecommunication and Electric Services
TR-106166 Final Report (RP4846-2)
Contractor: PNR and Associates
Business Unit: Retail Market Tools & Services
EPRI Project Managers: T. Henneberger, R. Gillman
Fax ID: 25412

Is There Value in Value-Added Services? Evidence From Competitive Markets in England, Wales, and Norway
TR-106195 Final Report (WO2343-19)
Contractor: EEE Ltd.
Business Unit: Retail Market Tools & Services
EPRI Project Manager: P. Sioshansi
Fax ID: 25454

Selling Value: How to Build Loyalty With Your Key Customers
TR-106281 Final Report (WO4845-2)
Contractor: ROI Management Corp.
Business Unit: Retail Market Tools & Services
EPRI Project Manager: T. Henneberger
Fax ID: 25615

Decision-Making Styles of Business and Industry: Five Insights to Improving Your Sales Success
TR-106298 Final Report (WO4845-1)
Contractor: Bramson-Gill Associates
Business Unit: Retail Market Tools & Services
EPRI Project Manager: T. Henneberger
Fax ID: 25650

Technology Assessment of Distributed Computing Environment (DCE) From Open Software Foundation (OSF)
TR-106319 Final Report (RP4888-1)
Contractor: Joe Waggoner & Associates
Business Unit: Information Systems & Telecommunications
EPRI Project Manager: A. Kader
Fax ID: 25682

Five Essential Tests of Market Strategy
TR-106389 Final Report (RP4853-2)
Contractor: Putnam, Hayes & Bartlett, Inc.
Business Unit: Retail Market Tools & Services
EPRI Project Manager: T. Henneberger
Fax ID: 25822

ENVIRONMENT

CO_2 Offset Opportunities in Siberian Forests
TR-106059 Final Report (WO4300-1)
Contractors: Applied Environmental Research, Inc.; Center for the Study of the Environment, EcoAnalysis, Inc.
Business Unit: Environmental & Health Sciences
EPRI Project Manager: L. Pitelka
Fax ID: 25222

Estimating Aqueous Releases of Polycyclic Aromatic Hydrocarbons From Coal-Tar Contaminated Soils at Manufactured Gas Plant Sites
TR-106291 Final Report (RP4301-2)
Contractors: University of Texas, Austin, Environmental and Water Resources Engineering Program; University of Florida, Soil and Water Science Department
Business Unit: Environmental & Health Sciences
EPRI Project Manager: I. Murarka
Fax ID: 25634

GENERATION

Advanced Gas Turbine Guidelines: Rotating Blade Temperature Measurement System (BTMS)—Supplement No. 1 (Durability Surveillance at Florida Power & Light's Martin Plant)
TR-105069 Final Report (RP3125-2)
Contractor: Fluor Daniel, Inc.
Business Unit: Gas & New Coal Generation
EPRI Project Managers: W. Piulle, G. Quenlin
Fax ID: 26094

Casting of ASHALLOY Metal Matrix Composites: 1993
TR-105822 Interim Report (RP9047-1)
Contractor: University of Wisconsin, Milwaukee
Business Unit: Environmental Control
EPRI Project Manager: D. Golden
Fax ID: 24811

Advanced Gas Turbine Cycle Studies: Summary Report
TR-105954 Final Report (RP2620-1)
Contractor: General Electric Co.
Business Unit: Gas & New Coal Generation
EPRI Project Manager: A. Cohn
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Header Feedwater Heater Retrofits in the United States
TR-105994 Final Report (RP3652-2)
Contractor: Encor-America, Inc.
Business Unit: Fossil Power Plants
EPRI Project Manager: J. Tsou
Fax ID: 25104

Materials Testing in a Syngas Cooler of a Coal Gasification Plant
TR-106010 Final Report (WO2093-3)
Contractors: EPRI; NV KEMA; Hoechst AG
Business Unit: Gas & New Coal Generation
EPRI Project Manager: W. Bakker
Fax ID: 25132

Casting of ASHALLOY Metal Matrix Composites: 1994
TR-106168 Interim Report (RP9047-1)
Contractor: University of Wisconsin, Milwaukee
Business Unit: Environmental Control
EPRI Project Manager: D. Golden
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Guidelines for the Use of Magnetic Bearings in Turbomachinery
TR-106185 Final Report (RP3319-3)
Contractor: Technology Insights
Business Unit: Fossil Power Plants
EPRI Project Manager: T. McCloskey
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Integrated Knowledge Framework (IKF) for Coal-Fired Power Plants, Vols. 1–3: Analysis of the Data, Information, and Knowledge Requirements for Economic Plant Operation and Maintenance
TR-106211-V1–V3 Final Report (WO9001)
Business Unit: Fossil Power Plants
EPRI Project Managers: M. Wildberger, R. Pflasterer
Fax ID: 25480

Proceedings: 1996 Heat Rate Improvement Conference
TR-106529 Proceedings (RP1681-11)
Contractor: Encor-America, Inc.
Business Unit: Fossil Power Plants
EPRI Project Manager: J. Tsou
Fax ID: 26033

Proceedings: 1996 EPRI Fossil Plant Maintenance Conference
TR-106753 Proceedings (WO3151)
Business Unit: Fossil Power Plants
EPRI Project Manager: D. Broske
Fax ID: 26416

NUCLEAR POWER

Software Fault Reduction Using Computer-Aided Software Engineering (CASE) Tools, Vols. 1 and 2
TR-105989-V1-V2 Final Report (RP4352)
Contractor: Science Applications International Corp.
Business Unit: Nuclear Power
EPRI Project Managers: S. Bhatt, A. Machiels
Fax ID: 25095

Proceedings: Eighth International RETRAN Conference
TR-106038 Proceedings (WO2853)
Business Unit: Nuclear Power
EPRI Project Manager: L. Agee
Fax ID: 25664

Insights From EPRI Maintenance Rule Projects
TR-106280 Final Report (RP3590-1, -2, RP3770-1, -2)
Contractors: QES, Inc.; ERIN Engineering and Research, Inc.; Applied Resource Management
Business Unit: Nuclear Power
EPRI Project Manager: J. Gisclon
Fax ID: 25613

Burnup Verification Measurements on Spent-Fuel Assemblies at Arkansas Nuclear One, Unit 1
TR-106305 Final Report (WO3290-7)
Contractors: Sandia National Laboratories; Los Alamos National Laboratory; Entergy Operations, Inc.—Arkansas Nuclear One
Business Unit: Nuclear Power
EPRI Project Manager: O. Ozer
Fax ID: 25659

Decontamination for Decommissioning: EPRI DFD Process
TR-106386 Final Report (WO3500-28)
Contractor: Bradtec, Ltd.
Business Unit: Nuclear Power
EPRI Project Manager: C. Wood
Fax ID: 25815

Evaluation of Expected Behavior of LWR Stainless Steel–Clad Fuel in Long-Term Dry Storage
TR-106440 Final Report (RP3290-10)
Contractor: Battelle Pacific Northwest Laboratories
Business Unit: Nuclear Power
EPRI Project Manager: R. Lambert
Fax ID: 25916

POWER DELIVERY

Proceedings: Substation Equipment Diagnostics Conference III
TR-105838 Final Report (WO2747)
Contractor: Cambias & Associates
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: S. Lindgren
Fax ID: 25139

Efficient and Economic Grounding Arrangements for Distribution Lines
TR-105907 Final Report (WO3127-3)
Contractor: Montana State University
Business Unit: Distribution
EPRI Project Manager: H. Ng
Fax ID: 24952

An Assessment of Distribution System Power Quality, Vols. 1–3
TR-106294-V1–V3 Final Report (RP3098-1)
Contractor: Electrotek Concepts, Inc.
Business Unit: Distribution
EPRI Project Manager: A. Sundaram
Fax ID: 25639

STRATEGIC R&D

New Approaches to Real-Time Expert System Design for Power Electronics Applications
TR-102205 Final Report (RP8000-40)
Contractor: University of Tennessee, Knoxville
Business Unit: Strategic R&D
EPRI Project Manager: B. Banerjee
Fax ID: 7442

Cycle Chemistry Guidelines for Fossil Plants: All-Volatile Treatment
TR-105041 Final Report (RP9003-2, -7)
Business Unit: Strategic R&D
EPRI Project Manager: B. Dooley
Fax ID: 23644

Impact of Lithium Abundance and Cost on Electric Vehicle Applications
TR-106556 Final Report (WO8061)
Business Unit: Strategic R&D
EPRI Project Manager: F. Will
Fax ID: 26081

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BIOPOWER
Version 1.01 (PC-DOS; Macintosh)
Contractor: SFA Pacific
Business Unit: Renewables & Hydro
EPRI Project Manager: Charles McGowin

C-VALU
Version 2.21 (PC-DOS)
Contractor: Christensen Associates
Business Unit: Power Markets & Resource Management
EPRI Project Manager: Connie Smyser

Engineering Calculator
Version 1.01 (PC-DOS)
Contractor: BSG Alliance/IT Inc.
Business Unit: Distribution
EPRI Project Manager: Harry Ng

FIVE™: Fire-Induced Vulnerability Evaluation
Version 1.0 (PC-DOS)
Contractor: Science Applications International Corp.
Business Unit: Nuclear Power
EPRI Project Manager: Robert Kassawara

GOTHIC: Generation of Thermal-Hydraulic Information for Containments
Version 5.0c (PC-DOS; UNIX)
Contractor: Numerical Applications
Business Unit: Nuclear Power
EPRI Project Manager: Avtar Singh

RPVDATA: Reactor Vessel Materials Database
Version 1.3P (PC-DOS)
Contractor: ATI Consulting
Business Unit: Nuclear Power
EPRI Project Manager: Stan Rosinski

SGDSM: Steam Generator Degradation-Specific Management
Version 1.0b (PC-DOS)
Contractor: Science Applications International Corp.
Business Unit: Nuclear Power
EPRI Project Manager: Robert Thomas

SSFR: Standstill Frequency Response Program
Version 1.0 (Windows 3.1)
Contractor: Rensselaer Polytechnic Institute
Business Unit: Fossil Power Plants
EPRI Project Manager: Jan Stein

WASTECOST DAW
Version 1.3 (PC-DOS)
Contractor: Environmental Resources & Services
Business Unit: Nuclear Power
EPRI Project Manager: Carol Hornibrook

EPRI Events

OCTOBER

10
Efficiency Improvements in Process Systems Using Adjustable-Speed Drives
Tulsa, Oklahoma
Contact: Carrie Koeturius, (510) 525-1205

10–11
PISCES Model Training
Irving, Texas
Contact: Lynn Stone, (214) 556-6529

14–16
Managing Fossil Generating Assets in the Marketplace
Washington, D.C.
Contact: Lori Adams, (415) 855-8763

14–16
Power Quality Interest Group Meeting
Cleveland, Ohio
Contact: Karen Forsten, (423) 974-8288

15–16
Using EPRI Land and Water Models
Dallas, Texas
Contact: Ishwar Murarka, (415) 855-2150

15–17
Substation and Switchyard Predictive Maintenance
Eddystone, Pennsylvania
Contact: Jeanne Harris, (800) 745-9982

15–18
Underground Transmission Course
Las Vegas, Nevada
Contact: Kathleen Lyons, (415) 855-2656

16–18
Tutorial: Preserving Equipment Qualification
Charlotte, North Carolina
Contact: Susan Otto, (704) 547-6072

17–18
EPRI Partnership for Industrial Competitiveness (EPIC)
Newport Beach, California
Contact: Bill Smith, (415) 855-2415

17–18
HELM Software Training
Dallas, Texas
Contact: Paige Schaefer, (800) 398-0081

17–18
Strategic Asset Management for a Competitive Utility Environment
San Diego, California
Contact: Susan Marsland, (415) 855-2946

18
NIALMS Users Group Meeting
Boston, Massachusetts
Contact: Jack Lemmerhirt, (508) 263-6080

21–23
Decision Analysis for Utility Planning and Management
San Diego, California
Contact: Charlie Clark, (415) 855-2994

22
Heat Rate Improvement
Long Beach, California
Contact: Jeanne Harris, (800) 745-9982

22–23
New Product and Service Development for New Market Environment
Boston, Massachusetts
Contact: Lynn Stone, (214) 556-6529

23–25
Achieving Success in Evolving Electricity Markets
Indianapolis, Indiana
Contact: Michele Samoulides, (415) 855-2127

23–25
Fuel Supply Seminar
Denver, Colorado
Contact: Susan Bisetti, (415) 855-7919

23–25
Healthcare Initiative Conference
New York, New York
Contact: Anne Kovalski, (718) 920-0849

24–25
HOTCALC Software Training
Irving, Texas
Contact: Lynn Stone, (214) 556-6529

NOVEMBER

3–6
Insulated Conductors
St. Petersburg, Florida
Contact: Jon Ferguson, (817) 234-8216

6–7
BWR Vessel and Internals Project Symposium
Lake Buena Vista, Florida
Contact: Madelaine Campbell, (415) 855-2879

6–7
CS 2000 Workshop
Chicago, Illinois
Contact: Mary Ann Neumann, (415) 855-2623

6–8
Distributed Resources, 1996
Vancouver, Canada
Contact: Lori Adams, (415) 855-8763

8
ASAPP2: Redesigned Software for Waste Accounting
Austin, Texas
Contact: Mary McLearn, (415) 855-2487

11–15
Utility Battery Group: Rural Electric Coop Market
Jacksonville, Florida
Contact: Steve Eckroad, (415) 855-1066

12
Application of Motors and Drives
Seattle, Washington
Contact: Carrie Koeturius, (510) 525-1205

12
Efficiency Improvements in Process Systems Using Adjustable-Speed Drives
San Diego, California
Contact: Carrie Koeturius, (510) 525-1205

12–13
Maintenance-Free Load Tap Changing: Phase 1
Tampa, Florida
Contact: Susan Bisetti, (415) 855-7919

12–14
Valve Packing: Application, Configuration, Engineering, and Program Development
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

13–15
Agricultural Technology Alliance Meeting
Raleigh, North Carolina
Contact: Chuck Sopher, (510) 937-4494

13–15
Lubrication Oil Analysis
Long Beach, California
Contact: Jeanne Harris, (800) 745-9982

14
Efficiency Improvements in Process Systems Using Adjustable-Speed Drives
Portland, Oregon
Contact: Carrie Koeturius, (510) 525-1205

14–15
Application of Motors and Drives
Los Angeles, California
Contact: Carrie Koeturius, (510) 525-1205

14–15
Electric Utility Forecasting in an Era of Deregulation
Dallas, Texas
Contact: Lynn Stone, (214) 556-6529

14–15
Electromagnetic Interference Qualification of Digital Equipment
Charlotte, North Carolina
Contact: Susan Otto, (704) 547-6072

14–15
1996 Heat Pump Allies Conference
Annapolis, Maryland
Contact: Michele Samoulides, (415) 855-2127

17–19
NSF Conference on Unbundled Power Quality Services
Key West, Florida
Contact: Gerry Heydt, (602) 965-8307

17–21
Research on Biological Effects of Electric and Magnetic Fields
San Antonio, Texas
Contact: Charles Rafferty, (415) 855-8908

18–20
Maintaining the Integrity of Water-Cooled Generator Stator Winding
Tampa, Florida
Contact: Denise Wesalainen, (415) 855-2259

20–22
Water-Heating Electrotechnologies and WATSIM Software Training
Irving, Texas
Contact: Lynn Stone, (214) 556-6529

DECEMBER

2–3
Power Electronics Applications Center Marketing Workshop
Knoxville, Tennessee
Contact: Karen Forsten, (423) 974-8288

2–4
Power Quality Technical Training
Knoxville, Tennessee
Contact: Karen Forsten, (423) 974-8288

3–4
Workshop on Wide Area Measurement Systems
Portland, Oregon
Contact: Dejan Sobajic, (415) 855-8537

9–11
Nuclear Maintenance Applications Center: 6th Annual Conference and Workshop
Orlando, Florida
Contact: Linda Suddreth, (704) 547-6141

11–13
1996 North American Electric Vehicle and Infrastructure Conference
San Diego, California
Contact: Pam Turner, (415) 372-0978

12–13
CHECWORKS Software Users Group Meeting
Colorado Springs, Colorado
Contact: Denise Wesalainen, (415) 855-2259

JANUARY 1997

5–9
1st World Congress on Microwave Processing
Lake Buena Vista, Florida
Contact: Eileen Mauro, (614) 421-3440

FEBRUARY

13–14
Municipal Water and Wastewater Program Meeting
Santa Monica, California
Contact: Kim Shilling, (314) 935-8590

17–19
Substation Equipment Diagnostics Conference
New Orleans, Louisiana
Contact: Michele Samoulides, (415) 855-2127

22–26
Environmental Concerns in Rights-of-Way Management
New Orleans, Louisiana
Contact: Myra Fraser, (415) 855-2507

MARCH

2–5
EPRI EMF Seminar
New Orleans, Louisiana
Contact: Robert Kavet, (415) 855-1061

2–5
2d International Workshop on Corrosion in Advanced Power Plants
Tampa, Florida
Contact: Michele Samoulides, (415) 855-2127

3–6
5th International Conference on Power Quality
Columbus, Ohio
Contact: Lori Adams, (415) 855-8763

3–6
Intermediate Underground Transmission Course
San Antonio, Texas
Contact: Kathleen Lyons, (415) 855-2656

25–27
1997 International Clean Water Conference
Baltimore, Maryland
Contact: Christine Lillie, (415) 855-2010

APRIL

14–16
Predictive Maintenance and Refurbishment
Florence, Italy
Contact: Susan Bisetti, (415) 855-7919

MAY

19–21
Substation Reliability-Centered Maintenance
Dallas, Texas
Contact: Denise Wesalainen, (415) 855-2259

20–22
Effects of Coal Quality on Power Plants
Kansas City, Missouri
Contact: Susan Bisetti, (415) 855-7919

JUNE

10–12
5th International Conference on Cycle Chemistry in Fossil Plants
Charlotte, North Carolina
Contact: Michele Samoulides, (415) 855-2127

15–18
7th International ISA POWID/EPRI Controls and Instrumentation Conference
Knoxville, Tennessee
Contact: Susan Bisetti, (415) 855-7919

JULY

21–23
1997 International Low-Level-Waste Conference
Providence, Rhode Island
Contact: Michele Samoulides, (415) 855-2127

23–25
EPRI/ASME Radwaste Workshop
Providence, Rhode Island
Contact: Michele Samoulides, (415) 855-2127

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