Plant Repowering

Also in this issue • Live-Line Work • Fossil Plant Simulators • Tires as Fuel

ELECTRIC POWER RESEARCH INSTITUTE

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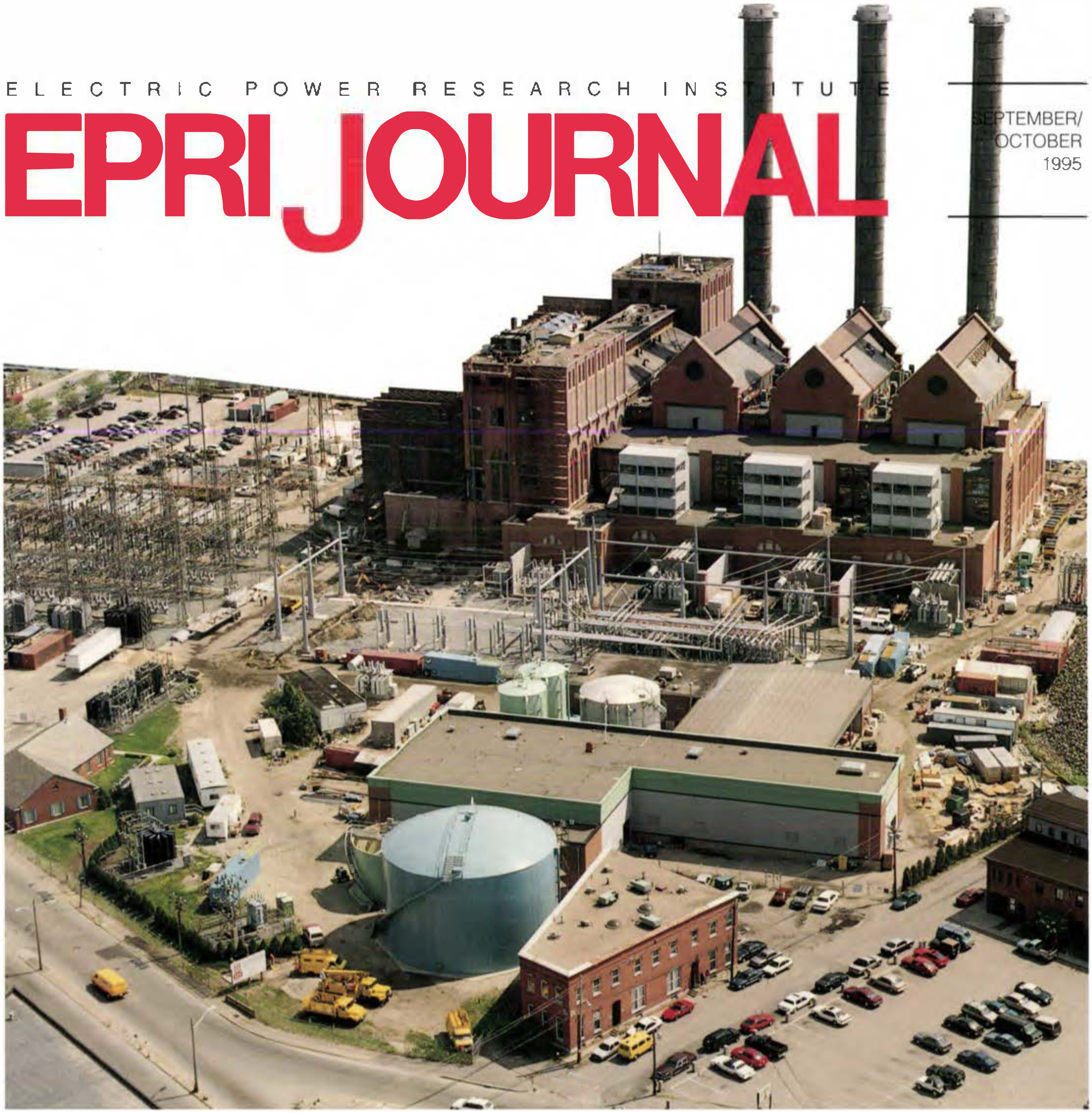

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Cover: In the nation's largest urban repowering project to date, the Manchester Street station in downtown Providence, Rhode Island, is being converted to a combined-cycle configuration that will more than triple its capacity. (Photo: Frank Giuliani; courtesy of New England Power Company)

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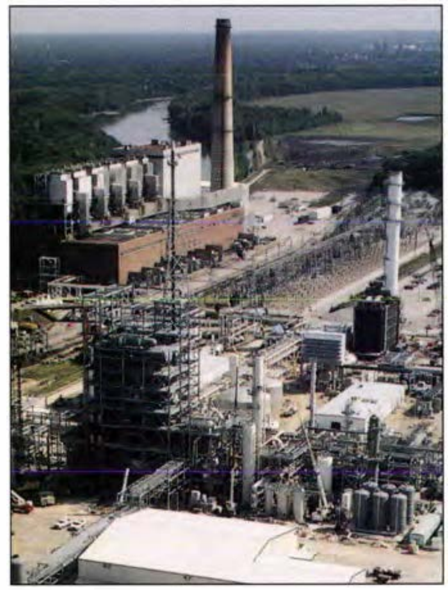

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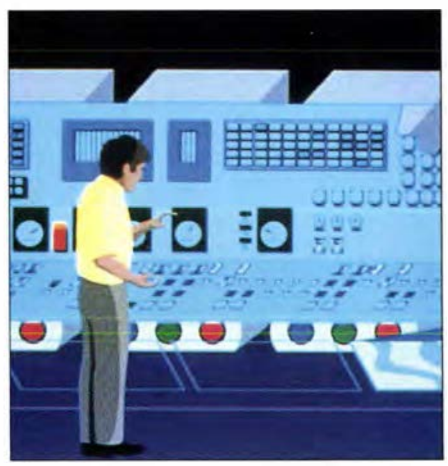

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Plasma Ladle Refiner

Developed jointly by EPRI and Maynard Steel Casting Company, the world's first direct-current plasma ladle refiner for foundry application improves casting quality while increasing the productivity of melting operations by 20–30%. The refiner is used to produce commercial grades of cast steel with very low levels of sulfur and oxygen. Other advantages include reduced melting energy use, precise chemistry control, and improved shop logistics. This product has received a prestigious R&D 100 Award. These awards are bestowed annually by *R&D Magazine*, whose panel of scientific experts selects 100 products it considers to be the year's most technologically significant.

For more information, contact the EPRIAMP Customer Assistance Center, (800) 432-0AMP. To order, call John Svoboda at the EPRI Foundry Office, (708) 427-9060.

Greenhouse Gas Workbook

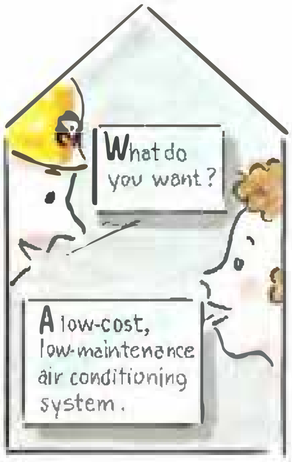
Electric utilities are increasingly interested in their greenhouse gas emissions and in options for reducing or offsetting them. Many of the least-costly options, such as forestry and methane recovery, involve activities and analyses not traditionally associated with electric utility operations. That's why EPRI developed the *Workbook for Screening Greenhouse Gas Reduction Options* and related spreadsheet templates. Using these tools, utilities can identify and evaluate the costs and benefits of a broad range of emissions reduction and offset options.

For more information, contact Tom Wilson, (415) 855-7928. To order, call Jill Staehler at Science & Technology Management, (414) 785-5940.

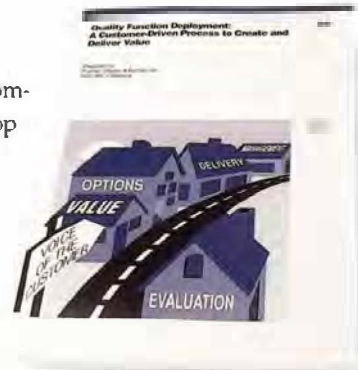
Transmission Costing Report

Mandated transmission access has created a critical need for electric utilities to analyze and evaluate the costs of transmission services. This two-volume report, *Transmission Services Costing Framework* (TR-105121), provides utilities with a means of accomplishing these tasks. Volume 1 presents technical and economic information that serves as the basis for transmission services costing, including key economic concepts and background information on transmission systems and their operation. Volume 2 presents a comprehensive framework for analyzing transmission services and evaluating their costs.

For more information, contact Ali Vojdani, (415) 855-2838. To order, call the EPRI Distribution Center, (510) 934-4212.

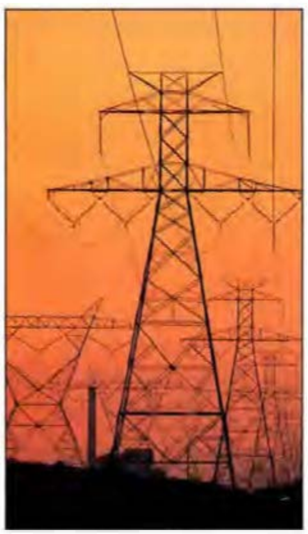


QFD Report



In order to thrive in what is proving to be an increasingly complex and dynamic marketplace, electric utilities must develop customer-focused products and services. The principles of quality function deployment, or QFD, can help them do this quickly and efficiently. QFD is a team-oriented decision-making process that draws on customer needs information to resolve product, service, and operational problems. The process originated in Japan two decades ago and is currently used by more than 100 firms in the United States. EPRI has adapted QFD principles for application in the utility industry. This report (TR-104663) describes QFD in detail and presents case studies that show how utilities can use the process to develop successful marketing and sales programs.

For more information, contact Thom Henneberger, (415) 855-2885. To order, call the EPRI Distribution Center, (510) 934-4212.



BaSES 2.0

Battery energy storage can offer electric utilities a flexible and strategically advantageous way to meet their energy management and power quality needs, particularly on the distribution system. To help utilities estimate the benefits and costs of battery energy storage plants, EPRI developed the Battery Storage Evaluation Software (BaSES), version 2.0, and an accompanying user's manual. An easy-to-use screening tool, BaSES 2.0 allows users to quickly tabulate the expected benefits of battery storage in such areas as capacity deferral, dynamic operations, and power quality. The program also calculates battery costs and helps users select battery sizes and enter key capital and operating cost data for specified scenarios.

For more information, contact Steven Eckroad, (415) 855-1066. To order, call the Electric Power Software Center, (800) 763-3772.

Thin-Film Electrolytes Lower SOFC Temperature

Solid-oxide fuel cells (SOFCs) avoid the handling difficulties of corrosive liquid electrolytes and have the potential to be manufactured and operated competitively in very small unit sizes. A critical problem, however, has been the relatively high operating temperature—about 1000°C—of SOFCs with yttria-stabilized zirconia (YSZ) electrolytes. Temperatures like this require the use of expensive ceramic interconnectors between adjacent cells and special grades of steel in support structures. Now a process has been developed to create thin-film YSZ electrolytes that operate at 700–800°C, low enough to allow the use of metal interconnectors and ordinary stainless steels in support structures.

The new electrolytes have a thickness of approximately 4–10 μm, compared with 100–200 μm for conventional YSZ cells, and are produced in a single deposition step. In this process, a porous electrode is coated with a colloidal slurry of YSZ powder; the slurry is allowed to dry, and the coated electrode is then sintered to yield a dense, pinhole-free film on the electrode support. Single, 1-inch-diameter cells created in this way have been subjected to tests of 300 hours, producing voltages and currents near the theoretical limits with no discernible degradation. The cells, which can operate at lower temperatures because of very low resistance across the thin-film electrolyte, produce very high power densities—in excess of 700 mW/cm^2 at 800°C.

Research on these thin-film fuel cells was conducted by the Materials Sciences Division of the Lawrence Berkeley National Laboratory, with support from EPRI and the Gas Research Institute. A key discovery of the research was that the quality of the electrolyte film can be increased significantly by careful preparation of the electrode substrate. Specifically, to avoid cracking of the fragile electrolyte during fabrication, the porous nickel-cermet electrode is prefired so that its shrinkage profile matches that of the thin film. Then, when the film and substrate are sintered to form a permanent bond, the film will experience not tension, which could fracture it, but compression.

Micrograph of thin-film YSZ electrolyte on porous electrode of solid-oxide fuel cell

"This is a very promising discovery, which should make small fuel cells more feasible," says EPRI project manager Wate Bakker. The next step, he adds, is to verify operating characteristics and endurance in a stack configuration. The SOFC test stacks will be built from 5 to 10 thin-film cells with a surface about 2 inches square and will use metallic interconnectors.

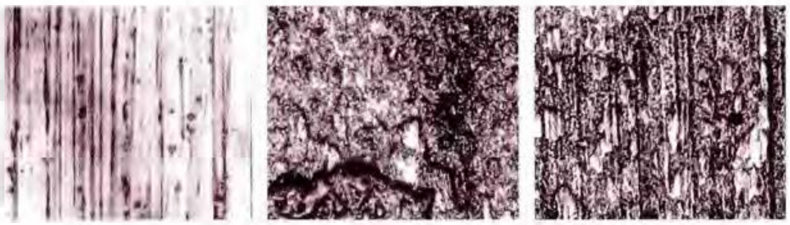
■ *For more information, contact Wate Bakker, (415) 855-2462.*

Search for Biopolymers to Prevent Corrosion

An estimated one-quarter of corrosion damage costs—equal to nearly 1% of the U.S. gross national product—might be prevented through the use of better protective techniques. Organic coatings, for example, can protect metallic surfaces against corrosion, but the cost of applying and maintaining them is often prohibitive. Now, Professors James Earthman and Thomas Wood of the University of California at Irvine have proposed a novel, inexpensive approach to corrosion prevention: let bacteria create the protective coatings.

The irony in this suggestion is that scientists are just beginning to understand the complex processes by which some bacteria accelerate the corrosion process. Such microbially influenced corrosion (MIC) affects a variety of steel and copper alloys used in many important commercial applications, such as underground pipes and nuclear power plant tubing. This corrosion is particularly difficult to prevent, and so far no MIC-immune material has been qualified for the nuclear power industry. Anaerobic sulfate-reducing bacteria (SRB) are often associated with MIC.

The surface of a fresh metal sample (left) clearly shows etch marks. After eight weeks, an unprotected sample (center) has corroded so much that the marks have disappeared. On a sample protected by a biopolymer (right), however, the etch marks are still visible.



What the UC researchers propose is to colonize the surface of metals with bacteria that secrete a protective polymer in which SRB cannot grow. Bacterial colonization is an especially attractive approach because it is inherently inexpensive and is automatically regenerative: if the polymer film is scratched, further bacterial growth rapidly coats it again. The trick, of course, is to find bacteria that can produce a suitable polymer while competing successfully with SRB and other deleterious bacteria.

The proposed three-year research program, which has just begun, will first use bacteria that naturally produce a film of polysaccharide glycocalyx, which helps them adhere to solid surfaces. Once this process is characterized, genetic engineering techniques will be used to create a new bacterial strain that produces the protective polymer in desired amounts and prevents SRB-induced MIC.

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

Strengthening Ceramics With Nanoparticles

During the late 1980s, Japanese scientists discovered that the mechanical properties of ceramics could be improved by adding ultrafine (100–200-nm) silicon carbide (SiC) particles. Subsequent work at Lehigh University, sponsored by EPRI and the U.S. Office of Naval Research, has confirmed this discovery and shed new light on the probable mechanism involved.

In general, ceramics tend to be brittle: when bent, they break easily, without deformation, along surface defects. Lehigh researchers have found that the presence of SiC nanoparticles apparently facilitates crack healing in the ceramic surface during annealing, thus making the surface stronger. In contrast, annealing a single-phase ceramic material actually makes surface cracks grow. According to the latest results, ceramic-SiC nanocomposites show a significant increase in high-temperature rupture strength, compared with single-phase ceramics. In addition, the creep rate of the nanocomposites is more than a hundredfold lower. The results also show large increases in abrasion resistance, which have yet to be quantified.

"These results suggest that the use of nanocomposites could have important applications in the utility industry—for instance, for wear- and erosion-resistant inserts and coatings in pulverized-coal conveying systems and fluidized-bed boilers," says EPRI project manager Wate Bakker. "Considerably more research needs to be done, however, to establish the optimal materials and processing parameters and to develop a commercial production method."

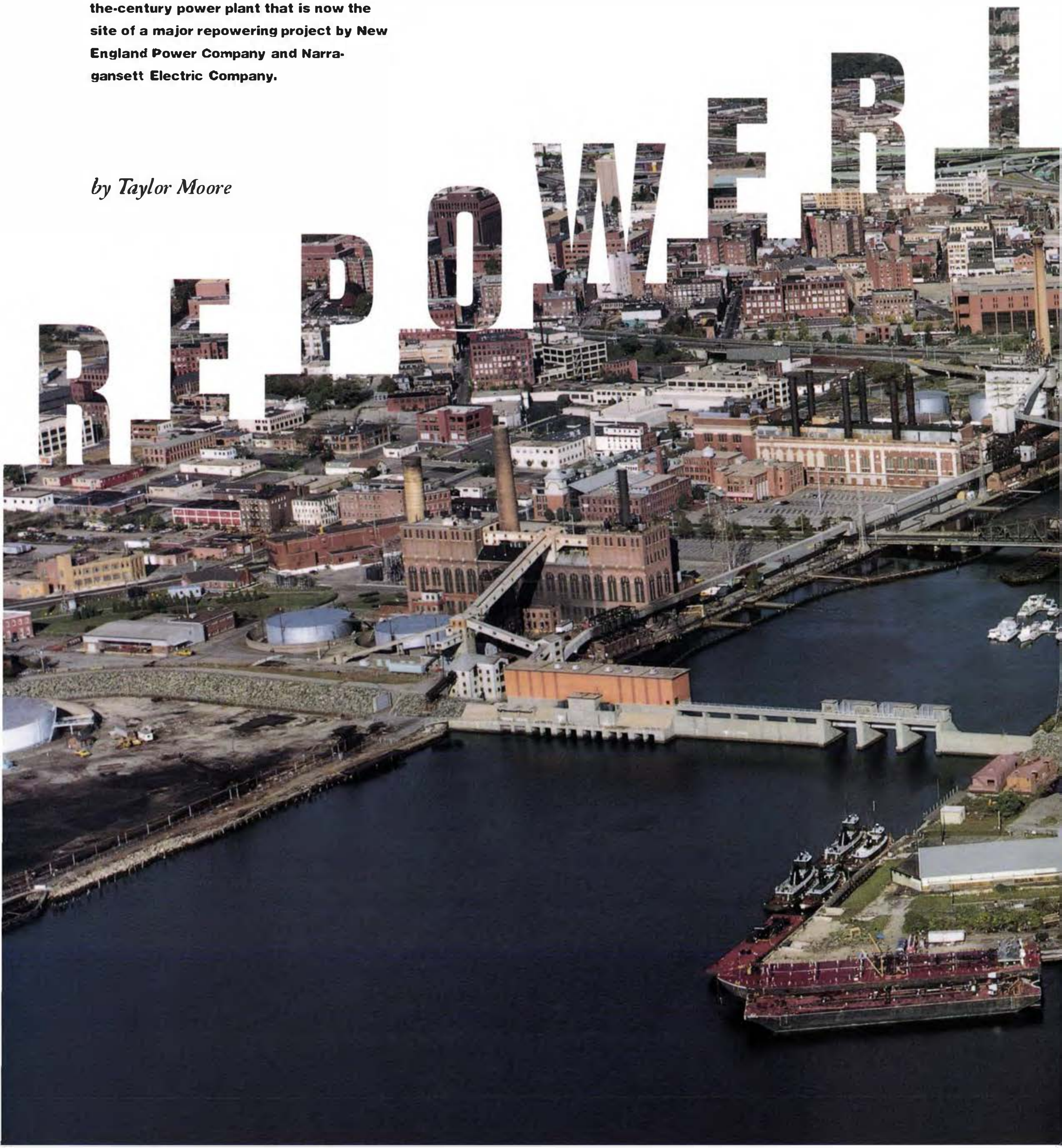
■ *For more information, contact Wate Bakker, (415) 855-2462.*

After annealing, a crack in an ordinary ceramic material (top) is much wider than a crack in a ceramic containing ultrafine SiC particles (bottom).

Visible in the left foreground along the waterfront of Providence, Rhode Island, is the Manchester Street station, a turn-of-the-century power plant that is now the site of a major repowering project by New England Power Company and Narragansett Electric Company.

REPOWERI

by Taylor Moore



Everlasting Images

NG as a Competitive Strategy

THE STORY IN BRIEF Repowering existing fossil power plants with new generating equipment and technology is emerging as the core of competitive strategies for transforming underperforming assets into some of the most efficient, low-cost capacity a utility may have. The substantial improvements in heat rate offered by various repowering approaches translate into reductions of similar magnitude in pollutant emissions, even as net generating capacity is doubled or tripled at a fraction of the cost of a green-field plant. EPRI is providing member companies a competitive advantage in the emerging repowering market with analytical tools and technical and market data that can maximize the strategic business opportunities represented by repowering projects.

The gathering winds of competition in electricity generation could breathe new life into the many aging and underused fossil power plants owned by today's regulated utilities. Repowering existing fossil steam generating units with gas turbines and combined cycles or with other new technology options is emerging as a centerpiece of competitive corporate strategies aimed at transforming relatively unproductive assets into more-efficient, low-cost producers. The approach flexibly combines elements of new generating technologies with existing facilities at established sites to reduce emissions and plant heat rates while boosting generating capacity at a highly competitive cost. Repowering may be the wave of the future for many of the country's older installed fossil generating plants that operate with low capacity factors.

"Once the limits of plant incremental operating and maintenance cost reductions are reached, older fossil power plants will become vulnerable to competition as the market-clearing price of electricity continues to drop," says Bill Weber, a project manager in the Gas & New Coal Generation Business Unit of EPRI's Generation Group and the organizer of the Repowering Applications User Group, or REPO. "Repowering marks the transition from a defensive strategy to an offensive challenge for market share."

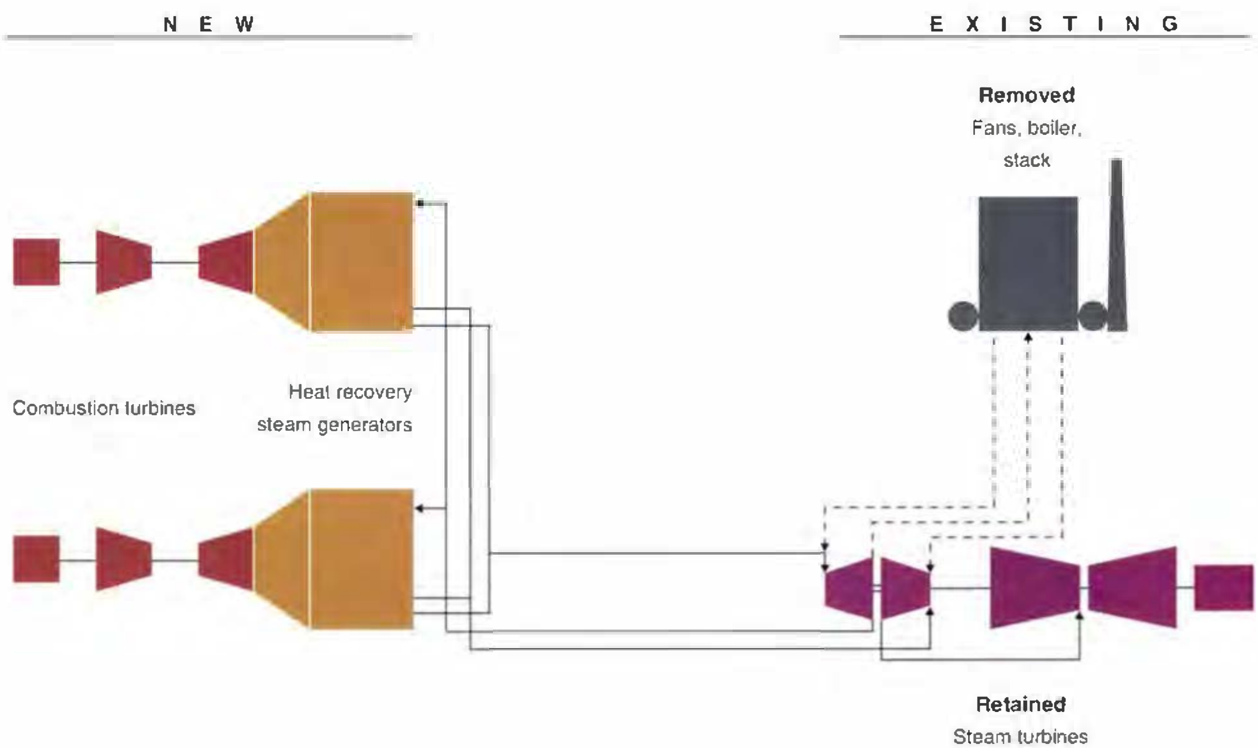
A repowering strategy can simultaneously address load growth, market vulnerability, environmental compliance, and technological obsolescence. "With deregulation and competition coming in the future, there will be opportunities for companies that decide that being a low-cost wholesale electricity generator is part of their core business; they can repower some of their underutilized generating assets to increase profit margins for off-system sales in a competitive power pool," Weber says. Repowering can also provide opportunities to forge partnerships with industrial customers located near an existing power plant—partnerships involving steam export or coproduction arrangements, for example.

In response to the needs of the emerging repowering market, EPRI has set a focused target designed to help members evaluate and apply the latest combustion turbine and clean coal technologies. Building on more than a decade of specific studies of proposed (and, in many cases, now completed) utility repowering projects, the Institute has a wealth of technical and market information to assist owners of existing plants in selecting repowering technologies that match available assets and market opportunities and in resolving the complex regulatory, permitting, economic, and environmental issues associated with repowering.

"Our objective is to help our members gain a competitive advantage by providing them with new planning tools and technical and market information they can use in assessing and optimizing the strategic benefits available from repowering," says Stan Pace, manager of the Gas & New Coal Generation Business Unit's strategic target on repowering, capacity enhancement, and new design. "Recognizing the competitive nature of the generation business, EPRI can work as a part of the project team to select the right technology and configuration to best match repowering options to project objectives."

REPO, currently composed of 23 EPRI member utilities, is an arena for transferring the Institute's resources and information and for interacting with the most successful technology providers and architect-engineers in the repowering market today. One powerful tool under EPRI development is engineering software for use in performing conceptual design analyses and comparative technical and economic evaluations of repowering approaches; it is expected to be commercially released next year.

OUT WITH (SOME OF) THE OLD AND IN WITH THE NEW **In a common type of gas repowering, a fossil-fired steam unit is converted to a gas-fired combined-cycle plant with the addition of one or more combustion turbines and heat recovery steam generators. Typically, the existing boiler, stack, and fans are removed or abandoned, while the existing steam turbines and related auxiliaries are retained as part of the repowered combined-cycle unit.**



Michael Melford

PSE&G's Bergen station

GAS REPOWERING, NORTH AND SOUTH **Two major utility gas repowering projects completed in recent years are Public Service Electric and Gas Company's Bergen station in Ridgefield, New Jersey, and Florida Power & Light Company's Lauderdale station at Fort Lauderdale. At Bergen, PSE&G installed four Siemens V84.2 combustion turbines with heat recovery steam generators to repower one of two existing 285-MW gas/oil-fired steam units for a net combined-cycle generating capacity of 650 MW. A second phase, planned for the late 1990s, would similarly repower the other Bergen steam unit, boosting the total plant capacity to 1300 MW. At Lauderdale, FPL installed four Westinghouse 501F combustion turbines in a combined-cycle repowering of two gas-fired units, increasing net summer capacity from 274 to 846 MW and, compared with new combined-cycle capacity, saving about $98 million in revenue requirements. Because of its significantly improved heat rate, Lauderdale has moved up in the dispatch order; formerly a little-used peaking plant, it is now a heavily used baseload plant.**

FPL's Lauderdale station

New capacity from old plants

Using already established sites and existing facilities can give repowering projects substantial cost savings (20–40%) over new construction at a green-field site and offers environmental, permitting, and other advantages as well. As a result, repowering is expected to account for a major share of the increase in generating capacity over the next decade. According to Jonathan Gottlieb, an attorney with the Washington, D.C., firm of Reid & Priest (an EPRI contractor) who advises utilities and other companies on such projects, some estimates indicate that repowering will account for half of all new capacity brought on-line between now and the year 2005. And there is plenty of older power plant candidate capacity. The U.S. Department of Energy has identified more than 3500 utility fossil fuel power plants that will be over 30 years old by 1998.

Gottlieb notes that "a utility repowering evaluation has largely been viewed as a technical and engineering issue. Few utilities have considered all of the sound business and financial reasons for repowering. Repowering is a business decision and should be viewed as an integral part of corporate strategic planning and repositioning. The legal, financial, contracting, and environmental aspects of repowering deserve greater attention from utility management. Refocusing the internal utility review of the repowering option presents a strategic opportunity as corporate utility reorganization and financial restructuring assume a more critical role."

For repowering projects to be successful in the emerging competitive wholesale electricity market, utilities must go beyond the conventional screening studies and plant performance analyses involved in identifying appropriate and economically attractive candidates for repowering; they must also identify customers for the repowered capacity before a project proceeds. "In many cases, the increase in capacity that can be achieved at an existing site through repowering will present an opportunity to serve existing customers with a least-cost option. In other cases, repowered facilities will be used to provide off-system sales to neighboring utilities or the power pool," explains Gottlieb. "In still other cases, utilities will repower their older facilities as exempt wholesale generators or sell older units to nonutility generators for redevelopment and repowering."

There are no significant technical differences in repowering an existing gas-, oil-, or coal-fired unit's steam turbine. However, there are important strategic differences between the two general types of repowering—gas and coal—according to Tom Hewson, an analyst with Energy Ventures Analysis who recently completed a repowering market study for REPO. In a common gas repowering approach, a fossil-fired steam unit is converted to a gas-fired combined-cycle plant with the addition of a combustion turbine and a heat recovery steam generator and some plant modification. Repowering with coal generally involves replacing the existing boiler in a coal-fired unit with some type of fluidized-bed combustion process or with coal gasification to fire a new combustion turbine. In both gas and coal repowering, the existing steam turbine and related auxiliaries typically are retained.

"Gas repowering to combined cycles can lower a unit's heat rate and, in turn, its variable operating cost, often to less than that of other fossil fuel steam units on the system," says Hewson. In some cases, the repowered unit may have a lower cost of generation than any other unit in a utility's generating mix. In a competitive market, that advantage can move a unit higher up in the dispatch order, thereby increasing its load factor and revenue potential.

"Going from poorly dispatched to heavily dispatched means that the additional revenue—coupled with the fuel savings—can justify a fairly large capital cost and still make an attractive return on investment in a reasonable payback period," continues Hewson. To date, gas repowering projects have been concentrated in areas where oil and gas figure prominently as baseload- and intermediate-capacity generating fuels: California, Florida, and the mid-Atlantic states.

Coal-fired units, in contrast, generally are relatively heavily dispatched as baseload capacity to begin with and already use a low-cost fuel. "Under present fuel price differentials, the level of investment you could justify from incrementally increasing fuel efficiency and improving dispatch through repowering with coal is generally smaller than for gas repowering," Hewson notes. But with fluidized-bed combustion or coal gasification, there are opportunities to burn lower-cost fuels, including high-sulfur coal (recently much less in demand than low-sulfur coal) and even the coal mining waste known as gob. Several utilities that have traditionally burned high-sulfur coal have considered repowering among various options for meeting new sulfur emissions standards, and a utility in Indiana is evaluating a fluidized-bed repowering project that would burn gob from nearby surface mines.

Gas repowering can be a way to save capital costs and reduce operating costs while adding capacity. It is expected to take a share of the generation market wherever gas-fired combined-cycle capacity makes sense. The rate of growth in the gas-fired market will depend heavily on the direction and rate of change of future gas prices, which are expected to increase from recent near-historic lows. But the list of utilities known to be considering gas repowering over the next five years is fairly long.

Coal repowering is a way to avoid having to retire useful units that may not be large enough to justify the capital investment otherwise required for compliance with new emissions limits. Because of the permitting difficulties expected for new coal-fired plants, analysts foresee a fairly large role for coal repowering for units in the 100–300-MW capacity range. Larger coal-fired units, around 500 MW and up, typically already operate with fairly low heat rates and generally may not be high-priority targets for repowering in the near term.

Matching technologies and systems

Common repowering approaches can range from moderate to major in terms of the plant modifications that are involved. In a repowering option known as hot windbox repowering, hot exhaust from a gas turbine is directed into the windbox of an existing boiler, eliminating the need for forced-draft fans and resulting in a heat rate improvement of up to 15% and an increase in generating capacity of up to 25%. Generally suitable for newer units larger than 300 MW, hot windbox repowering can cost as little as $150–$180 per kilowatt of total net capacity and can save a substantial fraction of the cost of new capacity at a green-field site.

Ten hot windbox repowering projects ranging in size from 159 MW to 695 MW have been successfully completed in the Netherlands; five of the larger units were repowered by EPON, a Dutch generating company. EPON and KEMA (the research and engineering services arm of the Dutch electric power system) are working with EPRI through its international affiliates program to offer technical expertise to U.S. member utilities that want to investigate

REPOWERING ON THE WATERFRONT **In the largest urban repowering project to date by U.S. utilities, New England Power Company and Narragansett Electric Company are repowering the Manchester Street station in downtown Providence, Rhode Island, originally built in 1903 to supply dc electricity for the city's streetcars. The plant's poor heat rate and low capacity factor led the utilities to decide to repower it with three Siemens V84.2 gas turbines and heat recovery steam generators. In addition to new construction and the rehabilitation of a historic structure, the project has involved installation of a new underground transmission cable and an under-the-harbor gas line. The combined-cycle repowering will more than triple the plant's capacity (to 489 MW), improve overall heat rate by about 25%, and significantly reduce air emissions. The repowered station is expected to begin operating around the end of this year.**

hot windbox repowering in tailored collaboration projects with EPRI. Recently, the New York Power Authority requested proposals for a study of hot windbox repowering at its 825-MW Charles Poletti power project near La Guardia International Airport in Queens.

Feedwater heater repowering—which, at $100–$150 per kilowatt, is the least costly and the simplest approach to repowering—offers a capacity increase of up to 30% and a 5% improvement in heat rate. It involves recovering heat from the exhaust of a gas turbine to heat feedwater entering an existing boiler. Considered a good application for new high-efficiency aeroderivative turbines in repowering recent-vintage fossil steam units, feedwater heater repowering could also represent a potential market for the new intercooled aeroderivative turbines being commercialized under the EPRI-led CAGT (Collaborative Advanced Gas Turbine) program.

Since, in some cases, feedwater heater repowering will require changes only to the feedwater system, it may offer the shortest installation time of the repowering options. It does require the availability of natural gas at the site, however, and the existing unit must be a baseload unit in order to achieve the improved efficiency.

Critical to the success of any repowering project is the transformation of a unit into a low-cost, efficient producer. The new systems must closely match the portions of the existing unit that are being retained and must be carefully integrated into the plant to obtain maximum performance and cost advantages. Unfortunately, repowering technology options are limited somewhat by the extraction-type turbine currently in use and by commercially available sizes of combustion turbines, fluidized beds, and even gasification systems.

"Atmospheric and pressurized fluidized-bed systems now commercially available can generally come close to matching the steam conditions of an existing steam turbine," says Arden Walters of Advanced Energy Research, an EPRI contractor. "But in combined-cycle repowering with a heat recovery steam generator, it can be harder to match the conditions of the existing steam turbine."

Walters, a former R&D manager at Florida Power & Light Company who was instrumental in that utility's pioneering Lauderdale plant repowering project, says that EPRI-developed cycle innovations, such as injecting steam into the gas turbine or humidifying the gas turbine compressor outlet air, offer options for using some of the excess steam that can accumulate in the lower-pressure stages of a steam turbine that is not optimally matched with a heat recovery steam generator.

"If the new equipment's fit with the older plant components is not pretty close to optimal, the repowered unit may not be able to compete," explains Walters. "If, compared with a new unit, a repowered unit suffers a little in performance because of constraints associated with the existing facilities, the capital cost savings from repowering have to be enough to make it a more cost-effective choice overall."

Utilities get involved

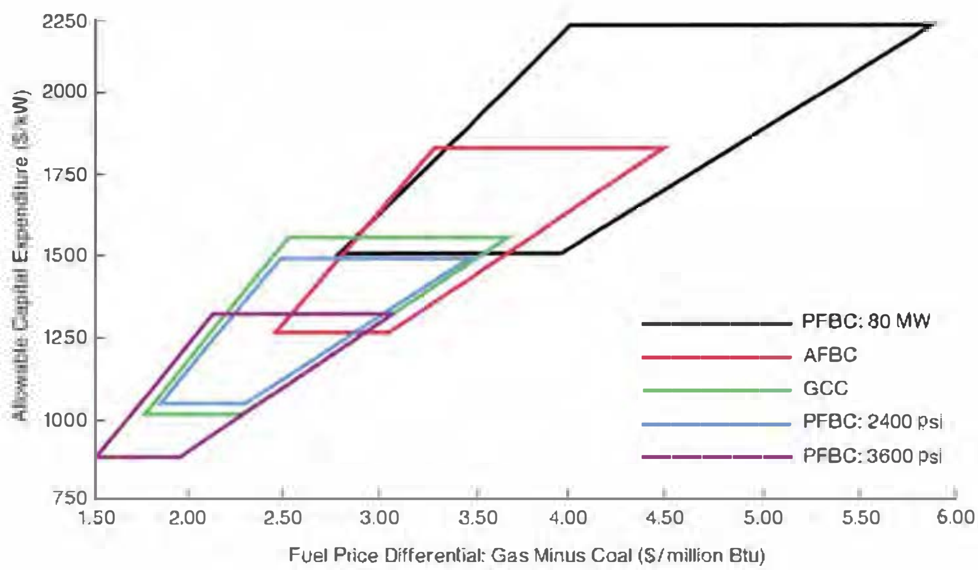
Part of the appeal of repowering, Walters notes, is that it offers the opportunity to change fuels if that promises to lower the variable cost of generation. Fuel flexibility is one reason Southern Indiana Gas and Electric Company is currently evaluating repowering one of its older units. EPRI is working with the utility in studying the feasibility of repowering an older coal-fired unit with a small atmospheric fluidized bed designed specifically for burning gob. Large quantities of this waste coal, which has about half the energy content of typical high-sulfur coal, are available from surface mines in surrounding counties in southern Indiana. Alternatively, the utility is considering a larger (250–300-MW) fluidized-bed unit of some type for a green-field plant at a new site that would also burn gob and coal fines in slurry form.

"We're working with EPRI and the members of REPO in pioneering how you analyze power plants to determine which are candidates for repowering and, given the specific constraints, what type of repowering would be best and what it would take to be cost-effective," says Bill Simmons, manager of generation projects at the Evansville, Indiana, utility and cochairman of REPO. Simmons says that both the repowering feasibility study and a study to characterize fuel issues should be completed by next spring.

"Right now repowering looks like one of the best ways to be competitive in the future," says Simmons. "Our repowering project under consideration would be about 70 MW if completed. It looks like you could repower a 100-MW plant for $800 per kilowatt, compared with $1200–$1300 per kilowatt for a new unit, and get an extremely good emissions reduction factor. If you can wind up with a more competitive unit and can switch to a waste fuel that reduces fuel costs, the strategy has a very strong appeal."

Over half of the more than 3000 MW of U.S. utility generating capacity that has been repowered to date has involved the addition of a gas-fired combustion turbine

COAL REPOWERING: WINDOWS OF TECHNOLOGY OPPORTUNITY **As the difference in price between natural gas and coal increases, windows of opportunity open for cost-effectively applying emerging clean coal-fired generating technologies at various unit sizes. The higher the price differential, the greater the capital expense that can be justified for coal repowering. The graph indicates allowable capital expenditure with an increasing gas-coal price differential for commercially available pressurized fluidized-bed combustion (PFBC) at 80 MW, atmospheric fluidized-bed (AFBC) systems in a range of unit sizes, gasification–combined-cycle (GCC) technology, and two higher-pressure PFBC systems expected to be commercially available in the near future.**



topping cycle and a heat recovery steam generator that replaces an existing boiler. This option, suitable for older 70–250-MW units with steam pressures of 1300–1800 psig, can increase generating capacity threefold and improve heat rate by as much as 30%, at a capital cost of about $500–$600 per kilowatt of total net capacity.

One of the more notable utility repowering projects nearing completion—the largest yet of a U.S. urban power plant—involves the Manchester Street station of Narragansett Electric Company in downtown Providence, Rhode Island. The project is a joint effort of Narragansett Electric and New England Power Company (both subsidiaries of New England Electric System). Built in 1903 on the waterfront to supply dc electricity for the city's streetcars, the station was converted to coal-fired ac generating capacity in the 1940s; it was converted to oil firing in the early 1960s and was further modified in the 1980s to burn natural gas as an alternative fuel.

Because of the plant's poor heat rate and resulting low capacity factor, the utilities decided in 1990 to repower the historic station with three 103-MW Siemens V84.2 gas turbines. This combined-cycle repowering project will more than triple the plant's capacity—from 132 to 489 MW—and will improve its overall heat rate by about 25% while decreasing air emissions significantly. Selective catalytic reduction units and steam injection into the gas turbines will be used to meet a very low NO_x emissions limit. "The repowered plant is expected to begin operating around the end of this year," says Bill Sullivan, manager of the project.

The future vision of repowering

Coal gasification represents an important hedge against future fuel price increases for natural-gas-fired combined-cycle plants and could enable repowered fossil steam plants to use the most economical grades of coal while meeting the most stringent emissions limits with state-of-the-art technology. It's also the repowering option that requires the greatest extent of plant modification. In this case, what is essentially a coal refinery is built alongside or near a suitable combined-cycle plant of at least 250 MW, and, using any of several commercial processes, this new unit converts coal to a clean synthesis gas for firing the gas turbines. EPRI was one of several partners in a consortium that first demonstrated the feasibility of integrated coal gasification–combined-cycle generation in the 1980s at the Cool Water station in southern California.

Gasification-based repowering is being demonstrated in DOE's Clean Coal Technology Program. PSI Energy, an Indiana utility subsidiary of CINergy Corp., has repowered a 100-MW steam turbine at its Wabash River station by adding a 192-MW General Electric Frame 7FA gas turbine that is fired with coal-derived syngas. The syngas is produced at an adjacent facility by Destec Energy, using gasification technology originally developed by Dow Chemical. PSI Energy is using EPRI's simulator technology for operator training and for fine-tuning the control system of this pioneering plant. (For more on simulator technology, see the article on page 20.)

Several utility gas combined-cycle repowering projects have included the evaluation and selection of phased coal gasification in system expansion and planning analyses. The relatively low price of natural gas and the high capital cost of gasification in comparison with other options have kept most plans for phased gasification on hold. One utility repowering project that has incorporated a phased approach to gasification in its plans is Public Service Electric and Gas Company's Bergen combined-cycle project, which recently

UTILITY DEMONSTRATION OF GCC REPOWERING **Gasification–combined-cycle repowering of an existing coal-fired unit is being demonstrated by the Indiana utility PSI Energy at its Wabash River station. Conducted under DOE's Clean Coal Technology Program and with cofunding from EPRI, the project is a joint venture with Destec Energy. A 100-MW steam turbine at the six-unit Wabash River plant (background) has been repowered with a 192-MW General Electric Frame 7FA combustion turbine fueled by coal-derived syngas from a Destec gasification plant (foreground, shown under construction). The repowered unit, the world's largest single-train GCC plant, has a net generating capacity of 262 MW and is expected to offer a 20% improvement in heat rate. Commercial operation was scheduled to begin in August of this year.**

began operation in Ridgefield, New Jersey.

Arden Walters of Advanced Energy Research says that confidence in the feasibility of adding gasification can provide significant support for a decision to repower with natural gas. Florida Power & Light relied extensively on EPRI data and technology in developing two site-specific designs for nominal 400-MW gasification–combined-cycle plants, and the cost and performance data for these designs figured heavily in the utility's decision to go ahead with repowering at its Lauderdale plant. "Both the utility and the Florida Public Service Commission needed to be convinced that coal gasification was a feasible fuel backfit for the gas units as a hedge against future high gas prices," explains Walters. "Having that hedge is valuable even if you never convert to coal because the feasibility of coal gasification effectively limits the potential for gas price rises."

A possible near-term market for gasification technology involves its integration into existing refineries, where it would use low-cost petroleum coke as a feedstock to produce gas for repowering adjacent steam generating capacity with combustion turbines. Such an application could lead to win-win partnerships between refineries seeking to utilize heavier crudes and utilities seeking to avoid loss of load to industrial generators and to obtain a source of competitive power. The Gas & New Coal Generation Business Unit is planning an initiative to assist utilities in working with refineries and other large industrial customers.

New tools for the new wave

The repowering-related modules of EPRI's State-of-the-Art Power Plant (SOAPP) software are important new tools that will soon be available for utilities to use in screening studies and detailed engineering analyses. SOAPP lets engineers perform analyses and develop conceptual designs for future power plants from a desktop computer. The SOAPP repowering screening module, slated for commercial release next year, can help identify and select repowering technologies for application to a specific user-defined unit. The module is expected to include cost and performance information on a full range of repowering options. Also scheduled for release in 1996 is a module for preparing preliminary engineering plans to replace a boiler with gas combined-cycle technology.

Rejuvenating veteran performers

"Recent advances in the performance of power-generating technologies will challenge many existing fossil power plants using dated equipment," says John Scheibel, manager of EPRI's Gas & New Coal Generation Business Unit. "An open, competitive market will seek out the bottom-line advantages of improved technology and reward early adopters. The combination of new generation technologies and underutilized generating equipment at existing sites offers a compelling opportunity to propel many older plants into the top-performing ranks of the dispatch order, making them key players in a more competitive future electricity market." ■

Background information for this article was provided by Bill Weber, Stan Pace, and John Scheibel of the Generation Group's Gas & New Coal Generation Business Unit.

Live Work


Haverfield

Hanging from a leather strap at heights of up to 140 feet is all in a day's work for people who tend the energized high-voltage utility lines that crisscross the country. While going about their daily business, they typically wear 10–15 pounds of tools like pliers, wrenches, hammers, and screwdrivers, plus another 50 pounds in belt hooks, safety boots, hard hat, rubber sleeves, and rubber gloves.

Whether workers use bare hands, rubber gloves, hot sticks, or helicopters, the occupation is called live work, defined by the International Electrotechnical Commission (IEC) as "the various methods used to carry out erection and maintenance, including connection and disconnection operations, on live parts of electric installations." Paul Lyons, EPRI's manager for overhead transmission lines, notes that live work also includes labor on deenergized equipment that is close to energized equipment.

According to the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor, injury statistics compiled by the Edison Electric Institute

by Perry Garfinkel

THE STORY IN BRIEF The practice of performing maintenance on live transmission lines has surged dramatically in the past two decades, as economic concerns have made the construction of redundant lines impractical. These days, utilities face the added pressures of the increasing demand for power and the need to accomplish tasks quickly with smaller crews. Responding to utility needs, EPRI launched the "Live Working 2000" project in 1993. Through this project, researchers conduct tests of new tools and techniques at the Institute's Power Delivery Center in Lenox, Massachusetts. The resulting data are made available to utilities and to regulatory groups that govern the practice of live working.

(EEI) and the International Brotherhood of Electrical Workers (IBEW) suggest that "overall incidence rates for the electric services industry . . . are slightly lower than corresponding rates for the private sector as a whole." However, line workers naturally face a greater risk of electric shock.

Joe Van Name Jr.,* chairman of the IEC's Technical Committee and an early innovator whom many consider the granddaddy of live work, described the work in this way: "If you do it properly, it's no more hazardous than driving a car." Nevertheless, researchers at EPRI, in conjunction with various agencies in the electric power industry, are striving to make sure that the risk to live-line workers continues to be minimal.

*Van Name died suddenly after this article was completed. His friends in the electric power industry requested that the piece be dedicated to his memory.

Focus on safety

Live-line maintenance of transmission lines began in the early 1920s and developed into a common work practice as the transmission systems were expanded and the voltages increased. In the 1950s, when transmission line voltages surpassed 300 kV, fiberglass replaced wood as the material of choice for tools of the trade. Over the last two decades, economic conditions have discouraged the construction of redundant lines, and the need for live-line work has surged. Concerns for safety have mounted as well. In the early 1970s, the Transmission and Distribution Committee of the Power Engineering Society of the Institute of Electrical and Electronics Engineers (IEEE) created a task force, which later became the subcommittee known as ESMOL (Engineering in the Safety, Maintenance, and Operation of Lines), to write a guide for the maintenance of energized power lines.

In recent years, several converging factors have further heightened safety concerns. The deregulation of the utility industry has created a more competitive environment in which costs have become a critical issue. That, in turn, has required that smaller crews do the same amount of work—or more—in less time. Such pressures are occurring at the same time that increases in population and production have put greater demand on utilities for power. So when maintenance problems arise, cutting off power to work on deenergized or dead lines has become increasingly impractical. In addition, the trend toward using compact line configurations means that workers may have to maneuver in tighter spaces to remain outside the danger zones.

Feeling the pressure of these new challenges, utilities approached EPRI in the early 1990s to initiate research in the area of live working. In response, EPRI launched its "Live Working 2000" research project in 1993. Through this project, EPRI aims to provide the fundamental technical data that utilities need—information on new techniques and equipment available for live working. Much of the research and testing for this project is conducted at the Institute's Power Delivery Center (formerly the High-Voltage Transmission Research Center) in Lenox, Massachusetts.

As Lyons, who manages the live-working project, explains, a major challenge of this research is to provide guidance for the practice of live working while "maintaining the delicate balance between safety and cost control." Currently, Lyons says, safety regulations tend to be conservative, mainly because of a lack of hard technical data on safe practices. "We're trying to use the experiments at the Lenox center to build on the existing pool of knowledge. Often, this new insight enables us to find more realistic and efficient practices for live working that are still perfectly safe for workers. This is significant, since the more conservative practices are more costly."

Lyons notes that EPRI's information alone is not enough to result in more realistic regulations governing live-working practices. "That," he says, "is up to groups like IEC, OSHA, IEEE, and IBEW. They have to accept and use our data—incorporating it into guidelines and standards—before a utility can rely on it for guidance. Otherwise, the utility may be held liable if an accident occurs."

There are some areas of live work for which guidelines are not even available. For instance, Lyons says, existing safety regulations offer no guidance for live work on compact transmission lines, which have come into use in the industry within the past 10–15 years. And until utilities have guidelines applicable to compact line configurations, they are unable to perform live work on these lines. "The information available pertaining to compact lines simply says you can't perform live work on such configurations—that the distance required between the worker and his tools and the live conductors is greater than that actually available in compact line configurations," Lyons says. "But safe distances change, depending on the object inserted into the field and on the voltages at the work site."

At a two-day "Live Working 2000" workshop last October, 20 representatives from utilities and standardization, regulatory, and enforcement agencies gathered in Lenox to provide feedback and input for EPRI's research. The research was described by George Gela, a contractor and research engineer for the center, and by Paul Lyons. "Our goal is to provide not only theoretical data but also empirical data, based on extensive, full-scale tests using protective equipment, to determine safe working distances and conditions for live work at all voltage levels," said Lyons. "The issue is reliability and continuity of service to customers."

DELICATE DANCE IN THE SKY
Over the past decade, the use of helicopters has virtually revolutionized live-line maintenance. A helicopter is an ideal tool for the trade, not just because it provides easy access to high places but—more important—because the air acts as an insulator, preventing the worker from becoming grounded. As is the case with other live-line maintenance techniques, proper distances must be maintained in order to prevent sparkover. One helicopter pilot describes the experience as "doing a dance together. When the line worker makes a move, you follow."

From the air

Another area of live work for which safety standards are being developed is helicopter use. According to Van Name, the

Photos: Haverfield

vice chairman of ESMOL's task force for helicopter safety standards, ESMOL—with help from electric utility personnel, helicopter services contractors, worker representatives, and other technical experts—has drawn up comprehensive guidelines for airborne live-line maintenance operations. Ultimately, the guidelines are expected to be submitted to the Federal Aviation Administration, which is likely to coordinate a memorandum of understanding with OSHA regarding worker and flight safety. ESMOL has also developed guidelines for helicopter-based insulator washing, while OSHA has adopted work rules related to helicopter landing zone procedures. The Helicopter Association International is developing additional guidelines.

In the last decade, helicopters have virtually revolutionized live-line maintenance. In one common helicopter-based maintenance technique, the line worker sits on the edge of a platform clamped to the helicopter struts while doing the work. The pilot's job is to hold the helicopter in a steady, hovering position only several feet from clusters of live wires. Since the worker bonds onto the line, energizing the helicopter as well, both line worker and pilot must wear conductive suits.

Only two companies, Haverfield and USA Airmobile, both based in Florida, provide helicopters and crews to conduct live-line work. From a cost- and time-saving perspective, the use of helicopters makes all the sense in the world; from the perspective of the person actually flying the machine, it makes none at all—at least at first. "I spent my whole career trying to avoid high-tension wires. Now I'm flying among them," says Michael Williams, who has been with Haverfield for one year. Before that, he flew in Alaska for the logging industry and in Hawaii on sight-seeing tours. "It looks risky from the ground, but once you're trained and realize it can be done safely, it's not hard at all."

One of the adjustments, he found, is being part of a team. "Helicopter pilots are used to working by themselves," he says. "It takes a little time to realize that someone else is counting on you. Slowly you learn that two heads are better than one. You're doing a dance together. When the line worker makes a move, you follow. I use his expertise and he uses mine."

Haverfield's business grew about 30% in 1994, an indication of the increasing popularity of helicopter use for live-line maintenance work. According to John Hanratty, the company's vice president for business development, Haverfield served more than 50 utilities last year.

At the center

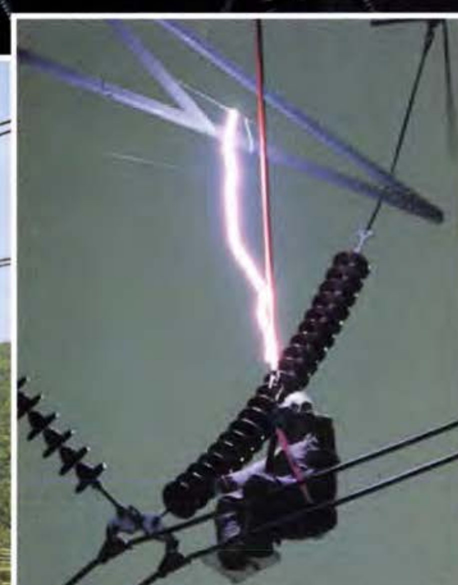
Because of the increased use of helicopters, EPRI has been testing the safety of two helicopter techniques at its Lenox, Massachusetts, center, one using a platform and the other a bosun's chair. In tests on the former technique, a fully operational helicopter was mounted on a 40-foot-tall insulated support structure between two phases of the longest test line (523 meters) at the Lenox center. Tests were conducted to determine the sparkover voltage as a function of the total air distance of the phases. For tests on the bosun's chair suspension method, a mock-up of a vertical tower configuration was set up to determine the sparkover distance from the simulated worker to the grounded tower parts. The mannequin

AT THE POWER DELIVERY CENTER

Most of the research and testing for EPRI's "Live Working 2000" project takes place at the Power Delivery Center in Lenox, Massachusetts (formerly the High-Voltage Transmission Research Center). Data resulting from full-scale tests of new techniques and equipment are made available to organizations that develop safety guidelines and standards for live-line maintenance.

Nighttime testing of an operating helicopter and a full-scale 800-kV system, with a wire mesh mannequin simulating the worker. This test is used to determine the minimum phase-to-phase distance necessary for preventing sparkover during night work. Sparkovers must not occur during actual service.

A daytime test shows the entire helicopter setup for a full-scale 800-kV line. Note the bonding spark occurring between the energized conductor and the wire mesh mannequin.



Testing of compact tower configurations is especially important, since safety guidelines for them are not yet available. This sparkover test features a mannequin in a bosun's chair.

In a full-scale compact tower setup, a portable protective gap is used to demonstrate that a worker can be protected from sparkover during live working.

in the bosun's chair was suspended from above with an insulating suspension system consisting of hot sticks and insulating ropes. The mannequin's vertical position relative to the energized phase was varied to investigate various work situations.

To guide its research at the Lenox center, EPRI relies on input from utilities, including the Western Area Power Administration (WAPA) and the Bonneville Power Administration, and from other organizations like IBEW, IEEE, IEC, and the American Society for Testing and Materials. Participants at the "Live Working 2000" workshop last fall had an opportunity to hear a presentation on EPRI's R&D to date and to offer their reactions. A brainstorming session at the end of the workshop helped EPRI's researchers prioritize their continuing testing. Participants said that they wanted more testing in the areas of damaged insulators, floating electrodes, and insulating protective equipment.

In the case of damaged insulators, EPRI continues to conduct tests to determine the maximum number of damaged or broken insulators with which safe work can be performed at 230, 345, and 500 kV. So far, testing has shown that the predictive equation currently used in the industry to determine this safety level is conservative. According to George Gela, additional research is required to come up with a more realistic equation that will allow safe work to be performed in a greater variety of conditions.

One of the areas in which EPRI sought feedback from workshop attendees was its testing of a portable protective gap (PPG), a gatelike device consisting of two 6-inch metal rods spaced to provide a 41-inch air gap. The PPG is installed on a transmission tower near the work area. Functioning as a spark gap, the device protects a worker from any excessive voltage that may occur by rerouting the voltage through the gap.

Ordinarily, there's a defined distance from a given live conductor at which it is safe to work; that distance is determined by the voltage of the line. But should an overvoltage occur, that distance would no longer be safe. One approach to determining the safe distance in the event of an overvoltage is to calculate it on the basis of the highest overvoltage that could ever occur on a given line. Using the PPG allows the safe working distance to be calculated on the basis of a much reduced overvoltage. Should a high overvoltage occur, the PPG would spark over and eliminate the high surge from the work site.

At the Lenox center, EPRI conducted sparkover tests with a PPG in a mock-up of a compact 550-kV tower. The tests took into consideration the presence of a worker (represented by a wire mesh mannequin on an insulating ladder), the location of the insulator cradle, the use of fixed and adjustable strain sticks, the number of damaged insulators, and the tower structure. The results confirm that the PPG can be used to provide positive overvoltage control at the work site. The project was cofunded by WAPA, which also provided insulators, hardware, and tower models. Some live-working tools were supplied by Pacific Gas and Electric Company and Safety Line, Inc.

Feedback for the future

One "Live Working 2000" workshop participant, Richard Strasia, a craft supervisor for transmission at Public Service Company of New Mexico, said that he was impressed with EPRI's work in the area of surge protection on 500-kV lines using the PPG. But, he continued, since his company works on 345-kV lines, "We'll keep watching and hoping." Recently, EPRI completed tests of adjustable PPGs that could be used on 345-kV lines. Information from these tests will be included in a live-working report, one in a continuing series on live-working practices that EPRI has published over the last two years.

Another workshop participant was Jim Dushaw, director of the utility department of IBEW, about 230,000 members of which are employed in the electric utility industry in the United States and Canada. He emphasized the need for greater communication among the engineers who develop equipment, the men and women in the field who use that equipment, and those who set safety standards. "Safety is critical to the mission of IBEW. It is one of the principles on which we were founded over 100 years ago," he said.

Other workshop attendees stressed the importance of disseminating research findings. Paul Lyons acknowledges the significance of this point as well: "We need to know what housetop we should be shouting from to distribute these data as widely as possible in as timely a fashion as possible." ■

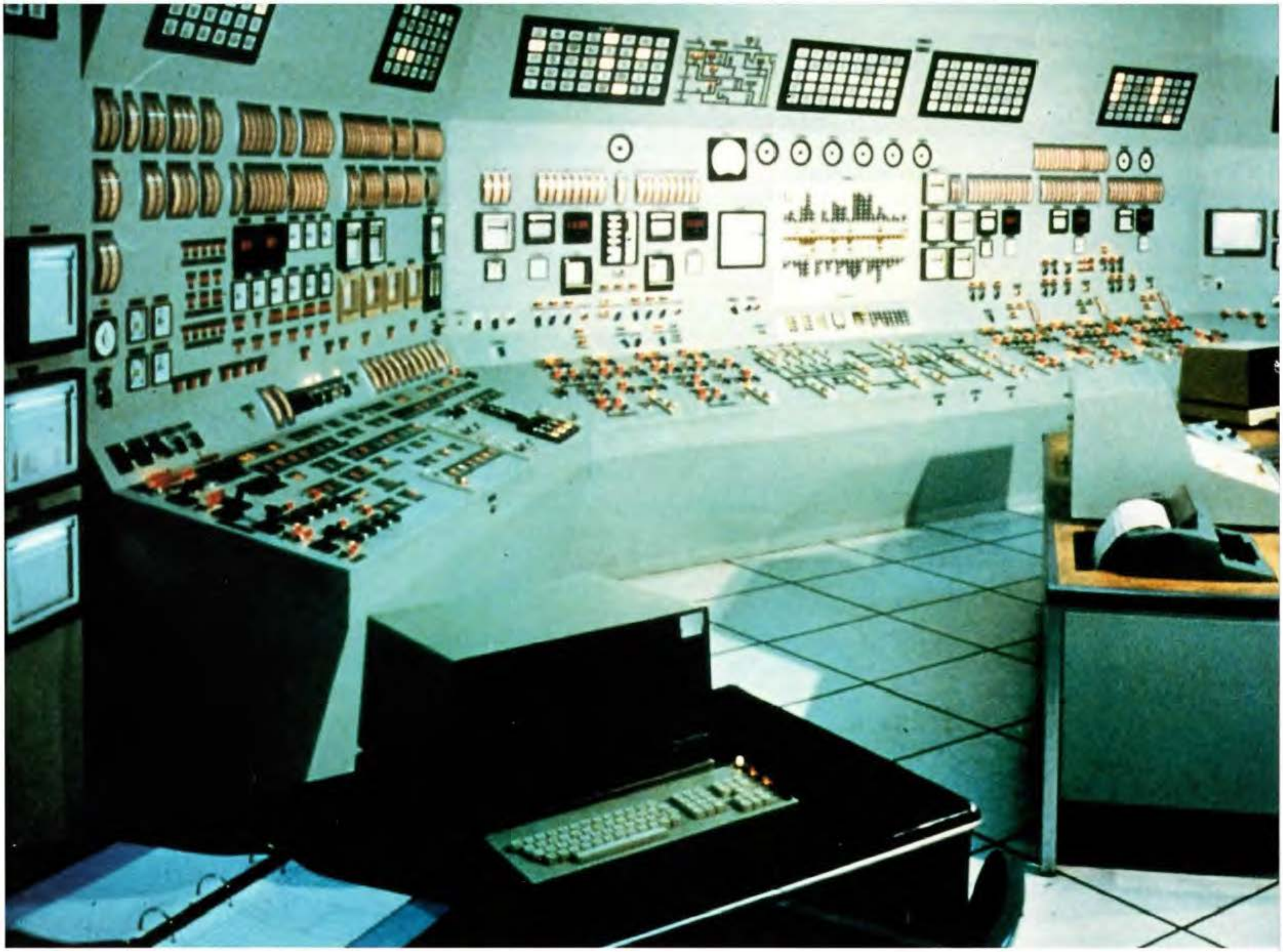
Further reading

Electrical Performance of Conductive Suits. Final report for RP2472, prepared by High-Voltage Transmission Research Center. March 1995. EPRI TR-104640.

Air Gap Sparkover and Gap Factors: Analysis of Published Data. Final report for RP3787, prepared by General Electric Company. December 1994. EPRI TR-104437.

Electrical Performance of a Portable Protective Gap (PPG) in a Compact 550-kV Tower. Final report for RP2472-4, prepared by General Electric Company. November 1994. EPRI TR-103860.

Background information for this article was provided by Paul Lyons of the Power Delivery Group's Transmission Business Unit.



Fossil power plant simulators have come a long way from the cumbersome and expensive systems of a decade ago (large photo). Today's fossil plant simulator technology (inset), which features integrated CRT-screen user interfaces, offers realism, flexibility, and, most important, affordability.

THE STORY IN BRIEF At a time when the utility industry is focusing on products and services that can enhance competitiveness, affordable fossil plant simulators are a welcome technology. In just a few years, these simulators have progressed from being an expensive tool that few utilities could afford to being a technology that many utilities feel they can't do without. Offering a variety of benefits in the areas of fossil plant training and engineering, today's simulators are flexible, effective, and much less expensive than their counterparts in the 1980s. A vigorous EPRI development and demonstration effort has advanced simulators beyond operator issues to a new era of application, ranging from the training of engineers to the design and testing of power plant technologies. And the technologies that have resulted from simulator development and enhancement will have beneficial uses beyond plant simulation.

A New Era for Fossil Power Plant Simulators

by Steve Hoffman

In the control room of a large pulverized-coal plant, an alarm sounds, signaling a boiler trip. The plant operator, though on the job for less than a year, confidently purges the boiler, starts the igniters, and fires the main fuel, all within 10 minutes, averting a unit trip. At an older plant across town, a new control system is being retrofitted. Although the system is not yet on-line, designers are methodically testing and debugging it. And in the parking lot of a utility's corporate offices, a group of engineers emerge from a trailer after evaluating a proposed expert system for one of their power plants.

What do these plant operators, designers, and engineers have in common? They are part of a growing number of utility personnel whose companies are benefiting from the use of fossil plant simulators. Regarded a few years ago primarily as aids to plant operator training, simulators are now seeing increasing service in a variety of plant applications.

Applying today's simulators to plant operator training offers several advantages over traditional on-the-job training in power plants. Since major malfunctions occur infrequently in a modern plant, training an operator to handle these problems as they arise could take years. With a simulator, component malfunctions can be simulated over and over in a single day. As a result, in one week of training, an operator can face more plant operating challenges than many operators would face in a lifetime. Then, when a problem arises during plant operation, the trainee can draw on lessons learned in these exercises to correct the problem quickly and efficiently. Such training minimizes plant downtime, reduces repair costs, and extends component and plant life.

Similarly, because baseload plants experience relatively few startups—many typically run nonstop for weeks or months—gaining significant experience with actual unit startups requires years. Using a simulator, operators can start the unit several times in one training session.

Simulator training has other benefits as well. Operators can learn how to operate the plant more efficiently, lowering its heat rate and reducing the power required by plant auxiliary equipment. They can be taught to anticipate problems and to take steps to avert them, improving plant availability and reducing the number of costly plant shutdown-startup cycles.

Applications like these can save utilities a lot of money. For example, Alabama Power Company estimates that it will save more than $23 million over 15 years by implementing a simulator-based training program for control room operators. Alabama Power's Dale Maddox explains that the utility gains "a competitive advantage because simulator-trained plant operators have the knowledge and experience necessary to operate units more efficiently, which will save money and keep our prices low."

Cost reduction needed

As recently as the mid-1980s, fewer than 10% of fossil plant operators received simulator training. The primary reason was high cost: a full-scope, high-fidelity simulator cost several million dollars. One cost driver was computer hardware. Ten years ago it took a $500,000 mainframe computer to accomplish what $50,000 worth of personal computers (PCs) can do today. Another major reason for the high cost of simulators was that to provide the realism required for effective training, it was necessary to replicate both control panels and logic. To do that, simulator designers provided a complete duplicate of the control panels commonly used in plants at the time—including, for example, switches, meters, and actuation lights—at a cost of over $1 million. Modifications to those controls were also expensive; replacing one instrument cost as much as $30,000. Moreover, techniques of developing software for simulator applications were cumbersome and inflexible, further adding to the cost.

At a conference on power plant simulators and modeling organized by EPRI in 1988, a group of utility representatives determined that expanded and enhanced simulator training was needed in the fossil generation industry. The conference attendees and utility advisors charged EPRI with defining and carrying out R&D efforts and transferring the technology to the industry.

Implementation of the R&D plan that EPRI developed in response to this mandate has helped reduce the cost of fossil plant simulators dramatically: as recently as six years ago, the cost was $2 million to $3 million; today it is $400,000 to $600,000. To achieve this reduction, EPRI has taken advantage of the PC revolution—implementing simulators on this low-cost hardware. A key Institute contribution is software that effectively translates programming from control system computers to PCs. These translators avoid the need to recreate control system logic and operator display screens, reducing simulator development costs by hundreds of thousands of dollars. As a result of these and other efforts, PC-based systems are the simulator of choice in fossil plants today.

Improving on operator training

Another significant EPRI contribution is simulator-based training programs. Training power plant operators requires more than a high-fidelity simulator. To be effective, a simulator must be combined with carefully designed simulator-based training programs that walk the trainee through training exercises, preprogrammed lessons, and simulations of malfunctions. Such training programs range from relatively simple lessons covering standard operating procedures (e.g., cold startup) to more sophisticated exercises (e.g., recovery from unexpected plant malfunctions).

Training programs harness the power of the simulator to optimize operator training. Developing these training programs is not easy, nor is presenting them to trainees. In the past, some utilities invested several person-years to prepare a comprehensive program and three or more months to present it. Responding to utility advisor requests to simplify and streamline this process, EPRI has produced guidelines for developing and implementing fossil plant simulator training programs. Several utilities have used the guidelines, published in 1993, to develop programs faster than they anticipated. Centerior Energy, for example, has reported significant reductions in the time required for training program development, initial training, and refresher training.

An extension of simulator-based training is EPRI's Intelligent Tutoring System (ITS). This system enables operators to receive training on a simulator even when an instructor is not present. Using expert system technology, the ITS tutors trainees on various aspects of plant operation during training exercises, prompting them when they make a mistake and providing on-screen information tailored to the error or situation. The ITS also offers positive reinforcement by comparing a trainee's performance with preestablished norms.

How the ITS works is best explained with an example. In a representative ITS training scenario, the plant's boiler has tripped, and the trainee is focusing on recovery operations at the simulator console. If in attempting to refire the boiler while maintaining generator connection to the grid, the trainee follows accepted procedure, no tutoring interaction occurs. If, however, the trainee makes a mistake—for example, failing to open several recirculation valves as required at the simulated plant whenever the load drops below 35 MW—the ITS console responds with a synthesized voice alert. The trainee can then listen to up to three levels of advice. The first level is a concise statement of the action needed. Experienced operators usually acknowledge this advice and continue the simulation. A less experienced operator can request a second level of advice, which describes the rationale behind the brief initial prompt. The third level of advice describes in detail the correct procedure to follow.

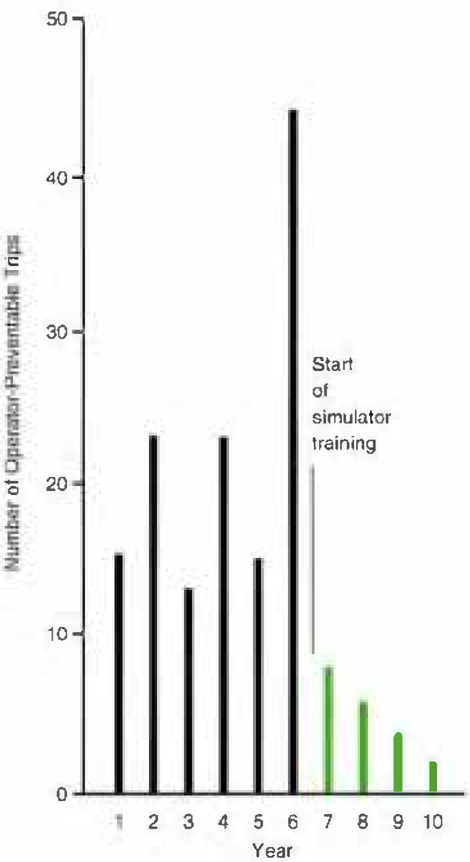
By making it possible to conduct exercises like these without an instructor, the ITS extends the usefulness of the simulator for training. "Our simulator will not sit idle if an instructor is unavailable," explains Jeff Pitts of South Carolina Electric & Gas Company, one of the first ITS users. "Operators can run simulator exercises themselves, logging many more hours of simulator training each year." The typical result is a 25% increase in the already significant dollar benefits of simulator training (e.g., through improved plant availability and reduced plant heat rate). Recently installed ITS modules are using a variety of multimedia features, including on-screen graphics, touch screens, voice synthesis output, and voice recognition. As more ITS training modules are developed for various generating units and types of training exercises, an ITS module library will be formed. Using a scenario editor equipped with an easy-to-use graphical user interface now available, utilities can modify existing modules and tailor them to specific plants or can build new modules and scenarios as needed.

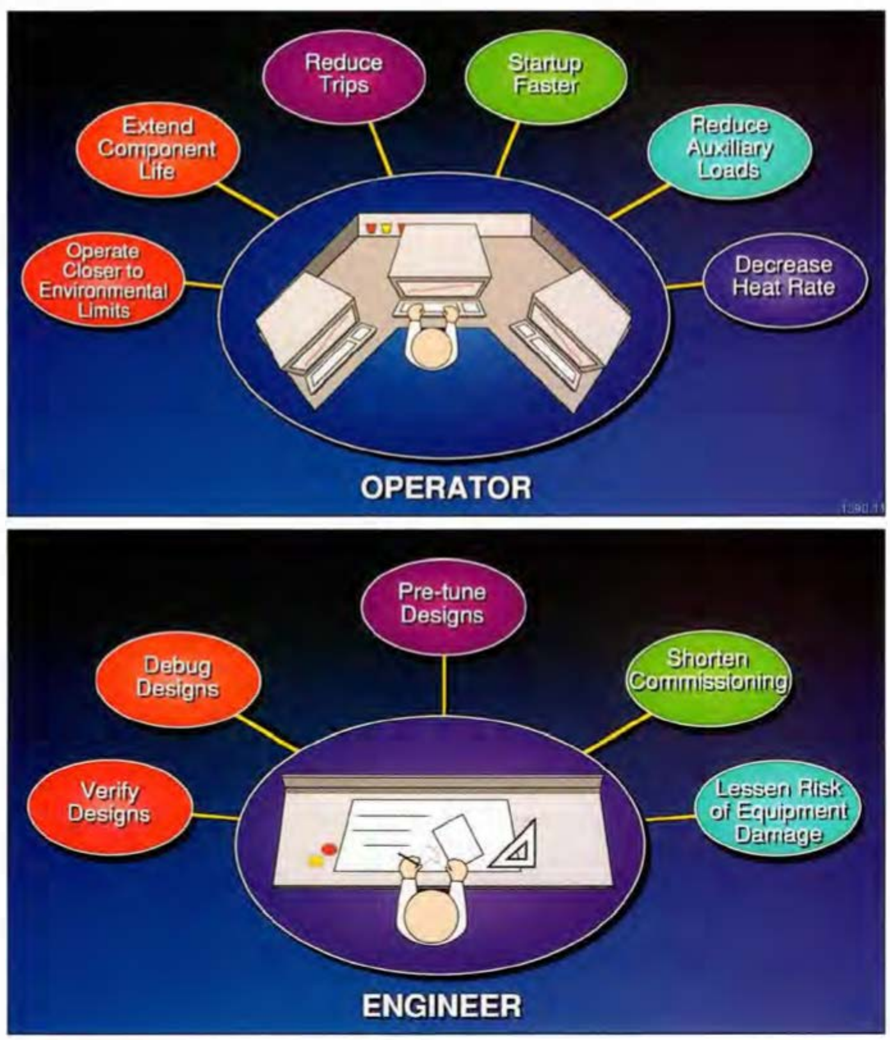
Tools like the ITS can help utilities optimize training budgets and trim costs. At utilities that are reducing training staffs, the ITS makes it possible to continue effective training. Another way a utility can keep training costs low is to carefully define its specific simulator-based training needs and implement a system that addresses only those needs. One utility, Kansas City Power & Light Company (KCPL), wanted to use simulator training to emphasize cognitive operating skills and decision making related to the plant process and its dynamics. For example, the simulator would help operators recognize indications that a pulverizer is reaching its operating limits. Conversely, KCPL wanted to use on-the-job training rather than simulator-based training to help operators learn the layout of plant controls and develop a feel for actual plant operation. Thus, on-the-job training without the simulator would cover hands-on control of the pulverizer. To help meet these training goals, KCPL and EPRI were able to design and develop a simulator for $272,000—about one-half the cost of a typical implementation.

Operators are not the only power plant personnel benefiting from simulator-based training. An increasing number of utility power plant engineers are learning more about plant operation by using simulators. Previously, few plant engineers received formal training in plant operation, despite the fact that engineers often address plant operation issues in their daily work. For example, to effectively upgrade or replace existing plant equipment, an engineer must first understand the operational demands placed on the equipment, the problems experienced with its operation, and its impact on other components. Such projects also require effective communication between engineering and operations personnel; engineers must speak the language of plant operation to understand typical operator duties.

Under EPRI sponsorship, Maine Maritime Academy has developed a simulator-based training program specifically for utility plant engineers. This program is now available to EPRI members and is used in a training course offered at the academy. In the course, instructors and trainees use a simulator for Alabama Power's Miller unit 4, a 660-MW unit that is typical of many

A WEALTH OF BENEFITS **Fossil plant simulators provide a wide range of benefits to utility users. For example, enhanced training using simulators helps operators prevent unit trips, achieve faster startups, and reduce heat rates—improvements that lower plant operating and maintenance costs. As illustrated by the bar graph for one three-unit station, many utilities have reported significant reductions in operator-preventable trips after implementing simulator-based training. Plant engineers can use simulators to debug, tune, and verify the design of new plant systems, such as the advanced control systems increasingly being retrofitted at fossil stations.**



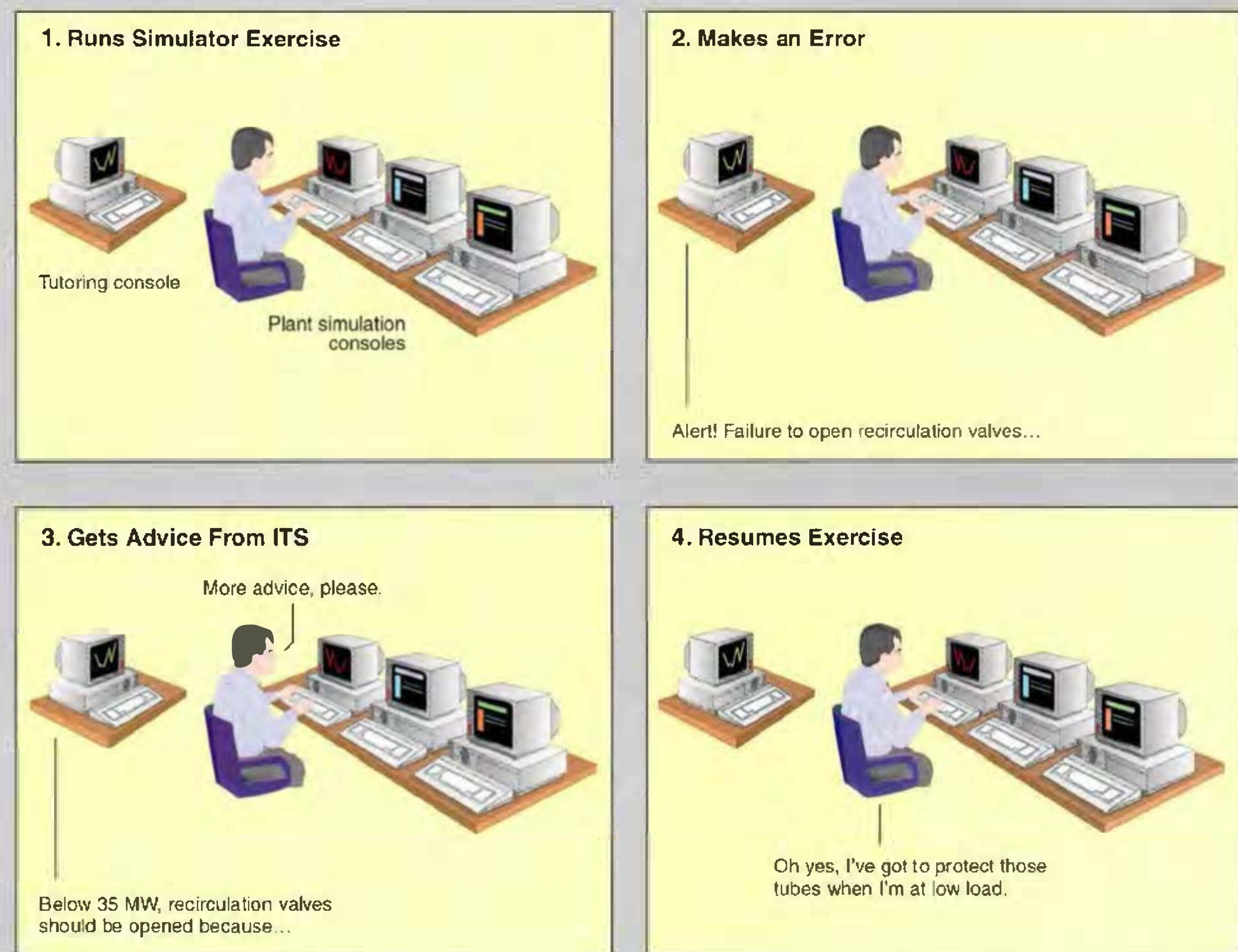


U.S. pulverized-coal plants. The course covers each plant subsystem and the interdependence of these systems and gives participating engineers a view of the plant as a whole. The participants acquire an understanding of the overall process of steam power generation, enhancing their ability to effectively communicate with operators.

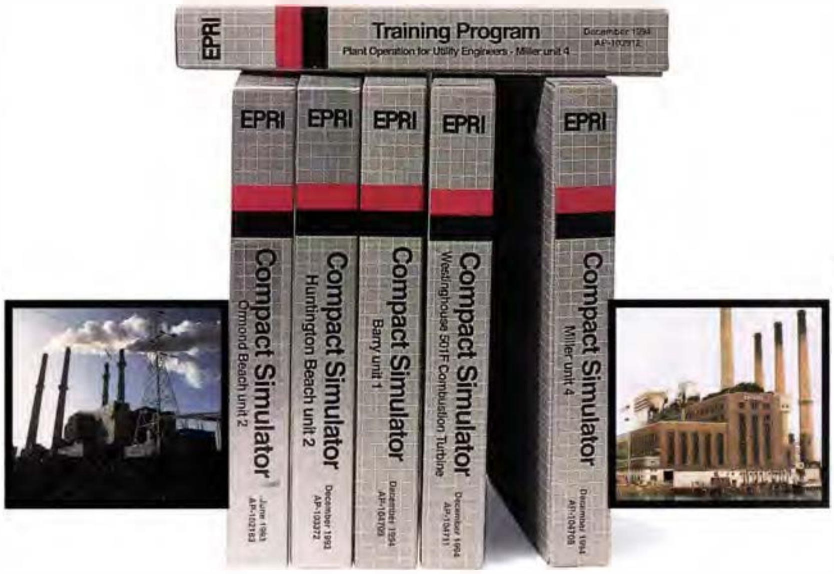
Control system engineering

One task that utility engineers are undertaking at more and more existing fossil plants is plant control system upgrading or replacement, and simulators are playing a major role in these efforts. The panel controls still in use at many older fossil plants are difficult to maintain because of parts unavailability. In the face of rising customer loads, high construction costs for new plants, and intensified competition to reduce rates and retain customers, utilities are placing greater performance and availability demands on these aging plants. One way to help meet these demands is to replace older control systems with state-of-the-art, microprocessor-based distributed control systems (DCSs).

Called distributed systems because they both physically and functionally distribute control tasks among several separate yet integrated computers, DCSs promise many advantages, including improved plant efficiency, increased availability, and extended component life. However, the DCS brings with it a different operator interface and method of control. Operators with years of training and experience on the old control system must learn a new approach to navigating through plant controls, a challenging task. A plant-specific simulator can smooth the transition to the DCS, allowing new recruits and seasoned operators alike



EXTENDING TRAINING CAPABILITIES **The Intelligent Tutoring System is an expert-system-based tool that lets plant operators take advantage of simulator training even when no instructor is available. In this typical ITS scenario, the trainee is conducting recovery operations after a boiler trip. When he fails to perform an important action, he is alerted by the ITS. Thanks to the system's voice synthesis and recognition capabilities, the trainee can obtain up to three levels of advice on the proper procedure without having to leave the simulation consoles. In this and other ways, the ITS provides a style of interaction similar to that of a human teacher.**



OFF-THE-SHELF SIMULATORS **EPRI's simulator library is a collection of plant-specific simulator models initially developed for individual utilities but then packaged for use by other EPRI members. Rather than having to develop a new simulator, a utility with a unit comparable to one simulated in the library can use the relevant library model—either as is or in modified form—to meet its needs. As other simulators are added to the library, more and more such matches will be possible. Scenario-by-scenario training programs and ITS training modules are also being added to the library.**

to practice a range of operations from standard procedures (e.g., unit startups, shutdowns, and load-following maneuvers) to rarely encountered events. If the simulator is specified for early delivery, operators can get up to speed on the DCS while the real control system is being retrofit.

During the first few months of DCS operation, while the new controls are being debugged, unit trips tend to increase and availability tends to decrease. A plant simulator can be used to verify DCS design, as well as to test, debug, and tune the DCS before its installation is complete. This process can identify DCS problems ranging from simple errors in input/output (I/O) parameters to design errors. An example of a simple I/O error is the specification of incorrect units for a temperature measurement (Fahrenheit versus Celsius). Once identified, such a problem is relatively easy to correct. In contrast, a fundamental design error, such as specifying the wrong type of controller for a specific plant function or using the wrong measurements, requires more effort to rectify. Failure to identify an error, whether simple or complex, could lead to a number of plant operational problems, including reduced efficiency, inadequate redundancy for safety purposes, and unplanned outages.

PSI Energy used a simulator to check out the new controls for its Wabash River coal gasification repowering project before the plant became operational. The utility loaded the project's control system software, which had recently completed acceptance testing, onto the simulator at the simulator vendor's factory. "What we found was a control system that was not ready to control the plant," says Marty Schafer of PSI. "We spent several weeks at the simulator vendor's factory identifying and resolving problems with the controls."

Several utilities have used simulators to support control system upgrades with beneficial results, and one utility, Duke Power Company, has made the most of simulator capability. In a joint project, EPRI and Duke developed two mobile simulator facilities that are flexible enough to emulate any fossil plant in the Duke system. Each of these mobile simulators is housed in two 28-foot truck trailers and can easily be moved from plant to plant. The simulators have served as engineering test-beds to design, debug, and tune replacement control systems throughout the utility's fleet of units.

One of the mobile simulators is now available for use by other EPRI member utilities for operator training, training program development, simulator development, plant operating procedure development, and control system design, validation, and training. The trailers, which can travel to a utility site as necessary, are based in Kansas City, one of two locations of EPRI's Simulator & Training Center. This S&T Center site is sponsored by KCPL; the other, in Houston, by Houston Lighting & Power Company. The S&T Center is the focus for continued EPRI efforts to enhance and expand fossil power plant simulator and training technology. Center staff conduct simulator and training research, develop and demonstrate products (e.g., tools, technologies, and courses), and provide research services for the benefit of EPRI members. In one example of available services, S&T Center personnel are supporting the design, development, and implementation of an operator training program at Pennsylvania Power & Light Company. Several other such projects are under way at the center.

A new kind of library

A key product of EPRI's effort is a simulator library—a growing collection of plant-specific simulators, simulator-based training programs, and ITS training modules. Each EPRI simulator development and demonstration project at a utility yields a simulator model that can be packaged like commercial software with an instruction manual and added to the library. To date, 6 models have been packaged in this way and made available to member utilities through EPRI's Electric Power Software

Center; more than 20 others are in a preliminary form and are in the process of being packaged. Together, these simulator models cover plants with a wide variety of fuels, boilers, steam turbines, combustion turbines, and control systems. Some of the EPRI-utility simulator projects are also yielding training programs and ITS modules.

While each volume in the simulator library was designed for a specific power plant, it has value at other plants and utilities. EPRI's Roy Fray, manager of simulators and training, explains: "A utility that has a unit similar to one of the units simulated in the library can use that simulator as is for training in cognitive skills, such as understanding the plant process and its dynamics. We have found that this type of training represents about 85–90% of the total training value of simulators." When other training goals, such as determining where each control is located (control geography) and getting comfortable with each control's operation, are also important, the utility can tailor the simulator to match its unit. Either way, using a simulator from the library involves less effort and expense than developing one from scratch.

In one of the first of several such uses of a library simulator, New York State Electric & Gas Corporation modified a model of Alabama Power's Barry plant almost three years ago to support a control system upgrade at its Milliken plant. As EPRI efforts continue, the library will grow, eventually including a sufficiently diverse number of simulators to provide a close match for almost any fossil plant.

In their contact with utilities that are interested in simulators and training, EPRI personnel come to know the utilities' major concerns. One expressed concern is how to economically meet emissions requirements. Many fossil fuel power plants that were originally designed for baseload operation have been converted to cycling duty and have been retrofitted with various emissions control systems. With the passage of the 1990 Clean Air Act Amendments, the effective operation of these systems has become paramount.

To avoid degradation in plant performance due to emissions constraints, some utilities are employing simulator-based training. At the New York Power Authority, one focus of simulator training is to help operators become more familiar with NO_x reduction systems at the utility's Poletti power plant. This training enables the operators to make optimal choices to comply with emissions control regulations. In light of the possibility of additional environmental regulations, more simulators are likely to be applied to emissions control optimization in the future.

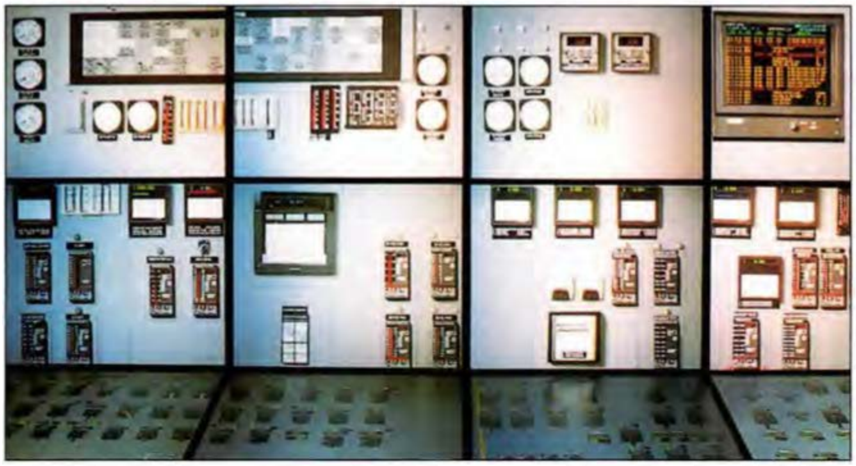
SIMULATOR ON WHEELS The Duke-EPRI mobile simulator, housed in two truck trailers, is flexible enough to emulate a variety of fossil plants and yet is easily transportable. The facility can support many applications, ranging from realistic unit-specific training to control system design and validation. It is available for use by EPRI members at its home base—the Kansas City location of the Institute's Simulator & Training Center—or at a utility site.

Look at that display

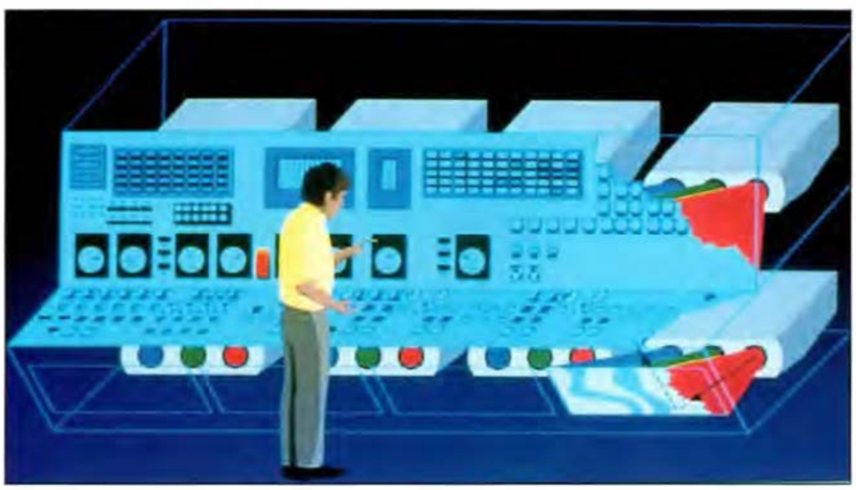
Developing simulator technology brings together many elements, including innovative modeling techniques, new training methods, state-of-the-art expert systems, human factors research, and advanced displays. One particularly innovative technology for simulator displays grew out of a need to affordably emulate control panels, which are still used at many U.S. plants and are likely to remain in use at some plants into the next century. Although computer screens (i.e., CRT displays) are now typically used instead of sheet metal panels in simulators, this solution may not be the optimal one. "While CRT monitors represent a much lower cost approach than panels, they don't provide operators with a good overall view of plant operating parameters and ready access to plant controls," explains Fray. "With CRTs, operators may have to page through many screens, pan around on screens, or zoom in on screens to find the controls they want. They have only a small window into the process at any one time."

EPRI-developed technology to emulate control panels overcomes this limitation of CRT display systems. Essentially, the panel emulation forms a wall of controls that look exactly like the actual controls, down to the tick marks on dials and the tags operators put on switches to indicate that they are out of service. The emulation is created by rear-projecting full-scale, high-resolution images of control panels onto large, touch-activated screens that the operator can use to actuate the controls. An array of these screens is used to present images of all plant panel controls simultaneously. EPRI has developed and delivered a full-scale panel emulation system to Boston Edison Company, which is using the system with its Mystic unit 6 simulator.

Emulated-panel technology provides a more realistic representation of the control panel than CRT displays. An operator can



ADVANCED DISPLAY TECHNOLOGY **Most of today's fossil plant simulators use computer screens, or CRTs, to display controls—an improvement over older simulator technology for hard-panel controls, which involved constructing duplicate panels out of sheet metal and equipping them with instruments. Because CRTs can't show all the plant controls at once, however, they don't provide easy access to all of them and don't give a complete view of plant operation. EPRI's new emulated-panel system, shown here as implemented in Boston Edison's Mystic station simulator, displays all plant controls simultaneously and in fine detail. The system works by rear-projecting full-scale, high-resolution images of the control panels onto touch-sensitive screens that the operator uses to actuate the controls. Beyond its application in simulators, this technology may soon move into actual control rooms to provide enhanced operator interfaces.**



view the entire panel at once and can easily read labels and scales on controls. While each individual control is at arm's length, a control room team can view the entire emulated panel by taking a step back. These features enhance realism, promote operator acceptance of the technology, and improve training effectiveness.

This technology may move beyond its role in simulator training to become the actual operator interface in control rooms of the future. Since the images of controls in emulated-panel systems are computer generated, designers can use the technology to change the look of actual controls to enhance clarity and ease of use, thus improving operator productivity and plant safety. A large display could show an overview of the entire plant process in schematic form. When an alarm flag pops up on a portion of the screen, the operator could touch the flag and view a subsystem process or component schematic that highlights off-normal parameter values. Recommended operating procedures to correct the problem, generated by an expert system, would be available at the touch of a button. Using such a system in plant control rooms could reduce costs through improved operation, enhanced power plant design and engineering, and extended plant life.

Hence simulator technology has come full circle: while the initial goal was to simulate the plant and its control room for training purposes, one key simulator technology may be applied in future control rooms for actual operations. As new industry concerns arise and new power plant technologies are developed, plant simulators are likely to be pressed into service as test-beds or proving grounds. Application to plant cycling optimization is now feasible, and integration with other plant diagnostic, monitoring, and control systems is envisioned. Taken together, these applications should provide extra value for utilities seeking to improve fossil plant operation and productivity. ■

Background information for this article was provided by Roy Fray and Murthy Divakaruni of the Generation Group's Fossil Power Plants Business Unit.

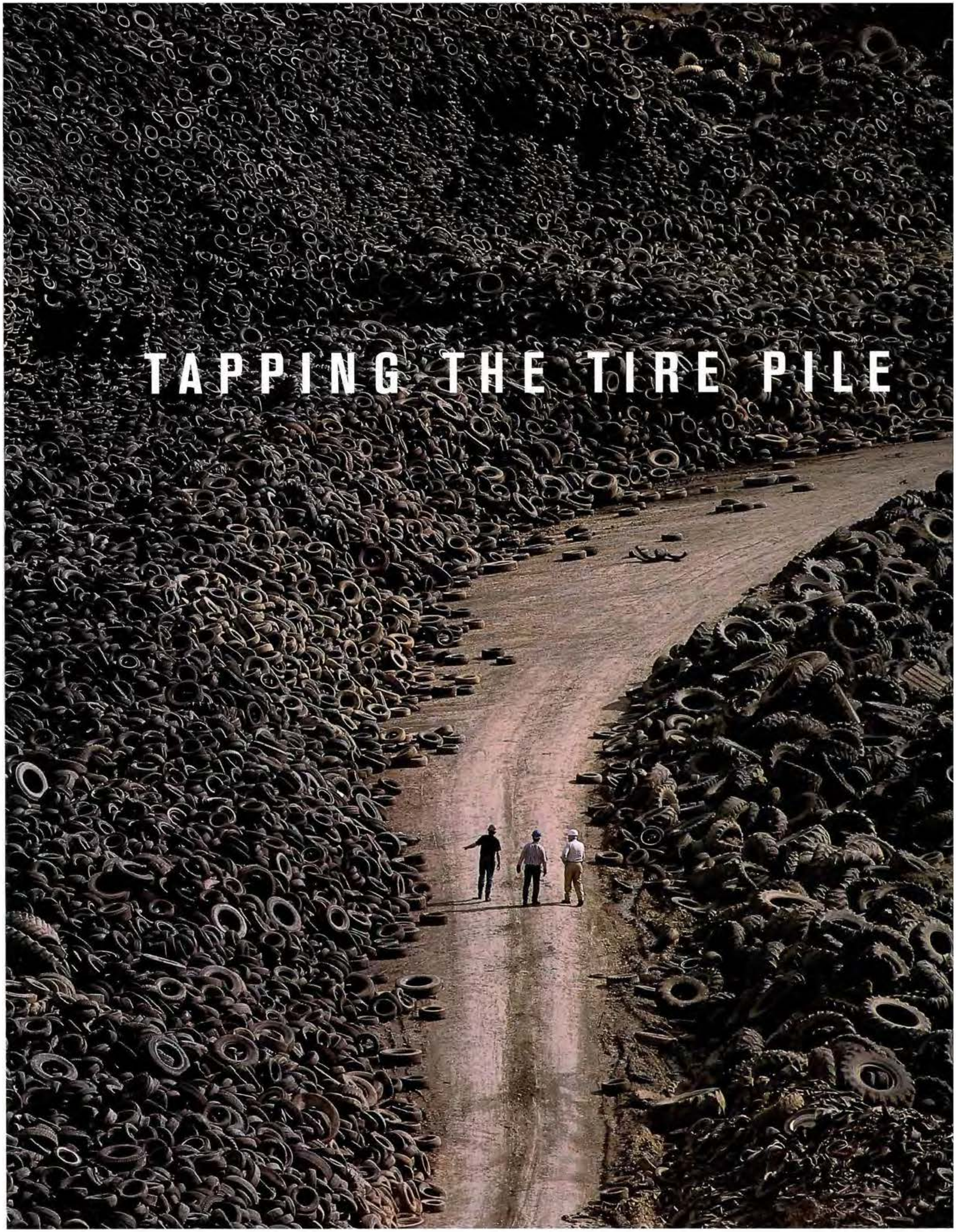
THE STORY IN BRIEF

What happens to car tires after they've exhausted their life on the road? Whether they are handed over to a tire dealer or tossed into the trash, many tires get a second life, reincarnated into products like doormats, park benches, and playground equipment. But the biggest single market for scrap tires is fuel—fuel that supplements the feedstock of paper mills, cement kilns, and even electric utility boilers. As well as offering a higher heating value than coal, tires can lower utilities' fuel costs and reduce pollutants like nitrogen oxides and ash. But it's the rare utility boiler that is amenable to burning tires successfully.

by Leslie Lamarre

Jose [illegible]/AURORA

TAPPING THE TIRE PILE



Old tires are a problem. Most landfills don't allow them because they tend to capture methane gas and float to the top of the garbage heap. And when discarded in tire piles, they collect rainwater and provide an ideal breeding ground for diseasecarrying mosquitoes. If tire piles catch fire, they can burn uncontrollably for days—even months—on end, spewing billows of acrid black smoke into the air and oozing oil into the ground.

Our nation has become obsessed with finding things to do with scrap tires. Spent tires have found their way into just about everything, from park benches to designer clothing. But these niche markets are nothing in comparison to the broad market for tires as fuel. The country's pulp and paper mills were the first to catch on to this idea. Cement kilns soon followed suit, and today they account for the largest percentage of scrap tire use.

A newer entrant to the tire-derived-fuel market is the electric utility industry. Starting in the late 1980s, utilities began to burn tires as a supplemental fuel in their coal-fired boilers. According to Michael Blumenthal, executive director of the Scrap Tire Management Council, the industry's interest in this practice is on the rise. "Utilities are fairly new to this game," says Blumenthal, "but there are more utilities interested than ever before, and the inquiries are far more serious than they were in the past."

As of July of this year, eight utilities were burning tires in their power plants on a regular basis, three were conducting test burns, and four others were investigating the idea. One incentive for using tires as a power plant feedstock is that some of the cost can be offset with money from state programs or through "tipping fees" received from the entity disposing of the tires. This can result in very low fuel costs. "Before competition increased in the industry, savings on fuel costs didn't mean as much, since fuel was an expense that could be passed on to consumers," says Chuck McGowin, who oversees EPRI's research on tire-derived fuel. "But now that utilities are competing with each other for customers, they want to keep their rates as low as possible. Cheaper fuel can help them do that."

In most cases, tires represent a small percentage of the fuel burned in a utility boiler—usually less than 10%. But even 3% of the fuel feeding a 365-MW plant is the equivalent of 6 million to 7 million tires annually. And that, Blumenthal says, "is more than just a drop in the bucket." According to the Scrap Tire Management Council, U.S. tire piles now hold some 850 million tires. And every year we toss another 250 million—about one for every man, woman, and child in the United States. In 1994, 138 million scrap tires were put to productive use; 27 million of them were consumed by power companies. The Scrap Tire Management Council predicts that consumption by power companies will increase to 40 million in 1995 and to 52 million in 1996.

Putting scrap tires to good use obviously helps resolve a potentially major health problem while eliminating a significant fire hazard and an eyesore. From a utility's perspective there are other advantages: tires have a high heating value (about 15,000 Btu per pound, compared with about 12,000 for bituminous coal and 5000 for wood), they are often cheaper and sometimes cleaner than coal (they contain less nitrogen than coal in general, as well as less ash than most coals and less sulfur than higher-sulfur coals), and using them provides an opportunity for positive publicity. "Burning tires in coal plants is a great way to tap the resource of an old plant that might otherwise be replaced simply because it can't compete," says McGowin. "The practice really strengthens the economics of these plants and helps utilities get more life out of them while providing a public service." But as many utilities that have investigated the practice can attest, making it work is not always easy.

Challenges, challenges

Most important, a utility has to have precisely the right type of boiler in order to consider burning tires. Experience to date has shown that cyclones and stokers work well. Unfortunately, they are also among the least common types of coal plants in the industry, with cyclone-fired boilers representing about 9% of all coal-fired capacity and stoker-fired units even less.

According to McGowin, most of the electric utility industry's experience with tire burning has involved cyclone-fired boilers. One great advantage of this boiler type for burning tires is that, in general, no modifications to the boiler itself are necessary. Typically, the only hardware needed is a conveyor system for feeding tire-derived

THE HAZARDS OF TIRE PILES

Tire fires, usually the result of arson, are one of the many potential hazards of the unsightly heaps of rubber that have accumulated across the United States. Shown here is a moment from a tire fire that raged in Hagersville, Ontario, for 17 days in 1990. As tire fires go, this one was mild. A similar fire in Winchester, Virginia, that started in 1983 burned continuously for nine months.

fuel to the boiler. And since tire-derived fuel has a lower nitrogen content than coal, emissions of nitrogen oxides from cyclone-fired plants (known to be high NO_x emitters) are reduced.

In order for tires to be used in cyclone boilers, the wire around the rim of a tire should be removed. Called bead wire, this material is much stiffer than the wire mesh beneath the tread of steel-belted tires, and if it winds up in the ash it can be problematic, since ash is often sold as a traction agent for use on winter roads. Says Bob Newell, manager for strategic energy options at Wisconsin Power and Light Company (WP&L), "The last thing you want to put on the roads is needle-like pieces of metal." Any metal left over from the combustion process can be removed with a magnetic separation device.

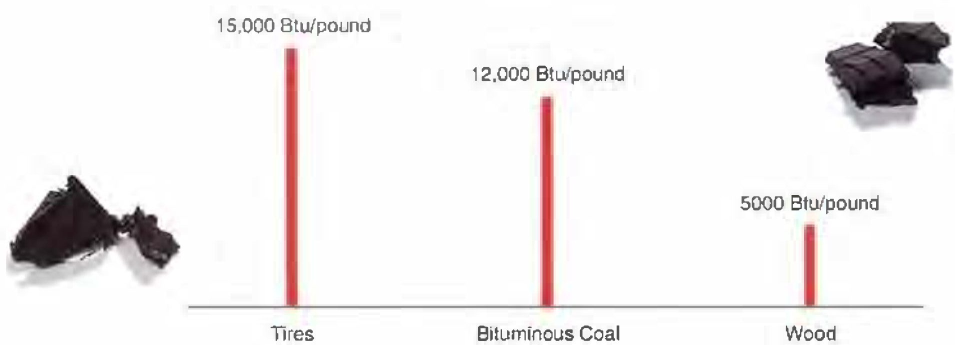
WP&L has been burning shredded tires in cyclone-fired boilers since 1989. Tests there, like tests in cyclones at other utilities, found that emissions from cofiring tires with coal were essentially equivalent to those from burning coal alone, although trace metals were reduced somewhat when tires were used and sulfur dioxide could vary, depending on whether the coal used had a low or medium sulfur content. Today WP&L uses shredded tires for up to 10% of the fuel in six cyclone boilers, eating up about 20,000 tons of tire fuel annually, or 2 million tires. The utility has found that tire chips measuring about 1 square inch are an ideal size for a cyclone boiler. If the chips are any bigger, it reports, there often is not enough residence time in the cyclones to ensure that the pieces are burned completely.

Illinois Power Company, which has been using tires for up to 2% of the fuel in two 560-MW cyclone units since early this year, has also found that 1-square-inch tire chips are ideal. According to David Stopek, coordinator of research and development for Illinois Power, such chips handled well in the coal feed system. "Even at 1 inch, there is some material that does not burn completely," he says, "but it's a very tiny fraction." He notes that his utility has installed a special system to remove this unburned material from the ash.

Stoker-fired units are also well suited for burning tire fuel, since the fuel sits on a moving grate near the bottom of the boiler, as wood sits on the floor of a fireplace. This results in a longer combustion period, enabling the fuel to burn completely. Utilities that have burned tire chips in stoker-fired boilers have found that chips measuring up to 2 square inches work well. Among them is New York State Electric & Gas Corporation, which has been burning shredded tires at Jennison station, a 74-MW plant with four stoker-fired coal boilers, since the spring of 1991. "We'll continue it as long as our stokers are around," says Wally Benjamin, a senior technical associate with the utility, adding that no major modifications were required for material handling—not even a conveyor system. Jennison station can burn fuel containing up to 25% tire chips by weight. As of July of this year, the plant had consumed the equivalent of more than 2.3 million car tires.

COMPARING COMBUSTION EFFICIENCIES

One reason tires make good fuel for coal-fired power plants is that they have a relatively high combustion efficiency, as indicated by the comparison here. Each 20-pound car tire contains about 300,000 Btu of heat energy, roughly equal to the amount of energy in 25 pounds of bituminous coal.



Other approaches

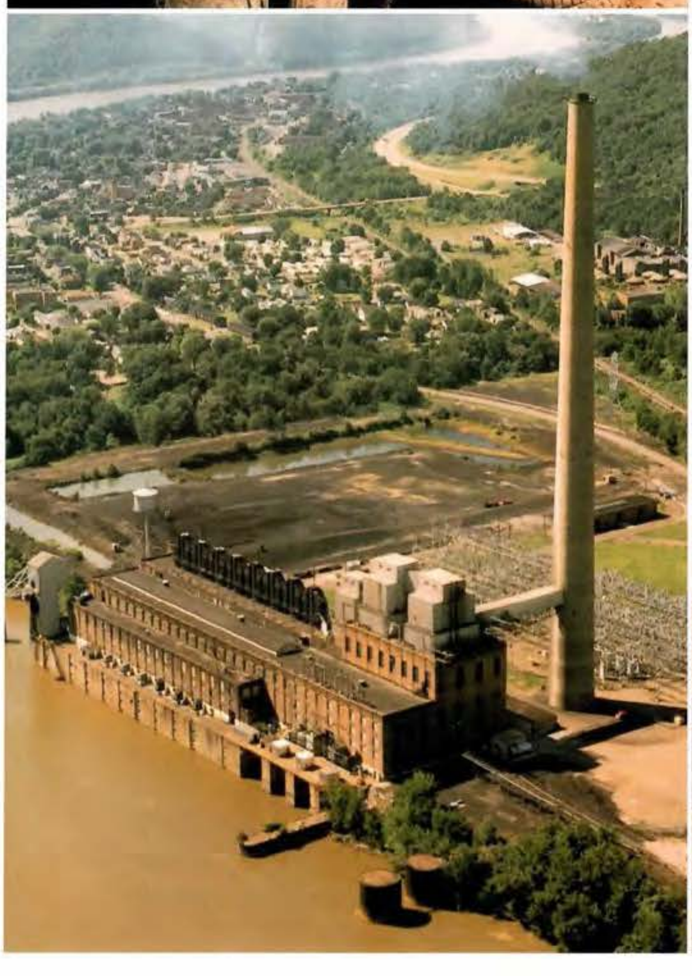
Pulverized-coal boilers, the most common type in the industry, are generally much more difficult to adapt to tire burning than are cyclone and stoker boilers. Before the coal enters the boiler, it is literally pulverized into a fine powder so that it can be burned in suspension. Although tires can be shredded into fine granules, such pieces are still larger than the coal particles, and the challenge is to get them to burn completely.

A recent EPRI study of finely shredded tire particles in a 65-MW pulverized-coal boiler showed that the particles burned rapidly but that the larger pieces, the char, and the carbon black in the rubber fell into the water-filled bottom of the ash hopper and burned on the surface of the water. EPRI's researchers concluded that in order to burn completely, this debris required a longer residence time than was available in the test unit. Only further testing can determine whether a larger pulverized-coal boiler would provide sufficient residence time to burn the tire material completely.

Ohio Edison Company took an entirely different approach to burning tires in a pulverized-coal plant by using whole tires. This enabled the utility to avoid the costly process of shredding tires for burning. Ohio Edison burned whole tires successfully in its 42-MW pulverized-coal boiler in Toronto, Ohio, for 18 months until the plant was closed in 1993 for unrelated reasons.

Augie Szempruch, director of project development for Ohio Edison, notes that burning whole tires is not a practice that can be carried out successfully at just any pulverized-coal plant. Characteristics

1



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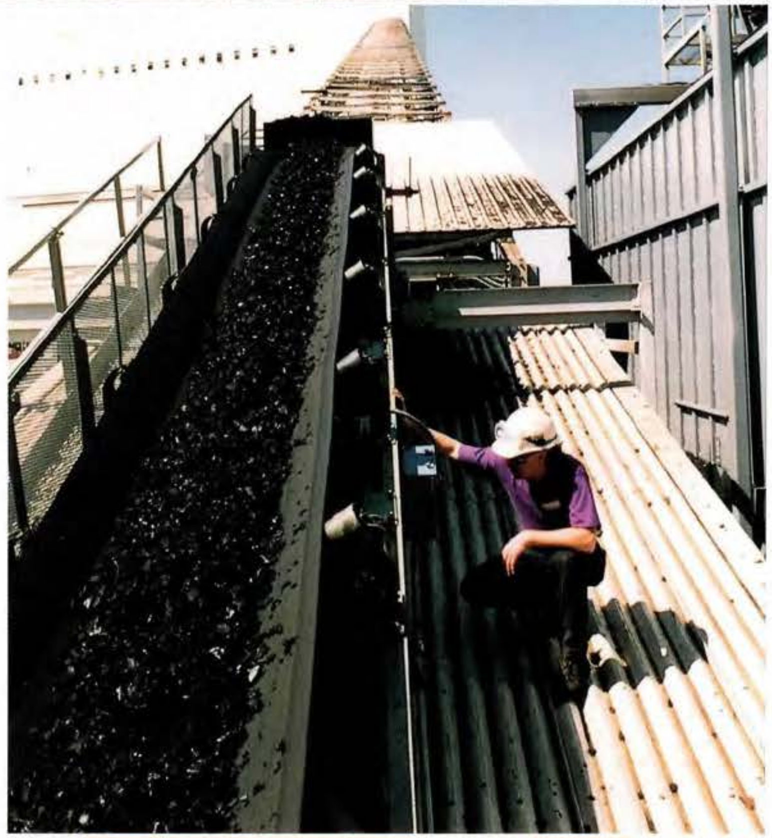

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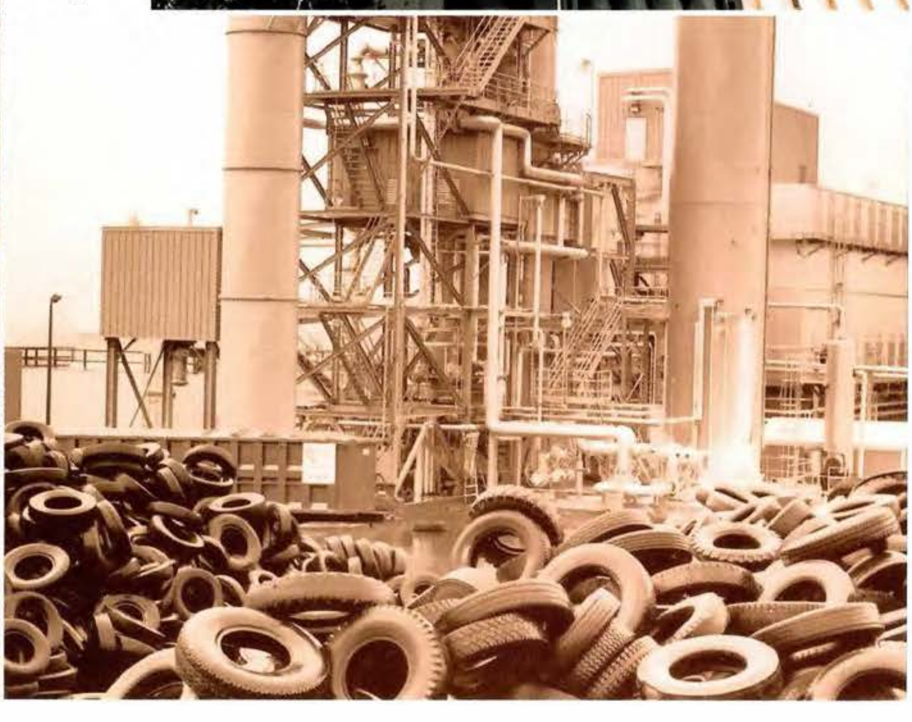

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POWER FROM TIRES
Electric utilities have been turning tires into power since the late 1980s, mostly in coal-fired boilers. Here are just some examples of the industry's tire-burning experiences.

1
Wisconsin Power and Light uses scrap tires for up to 10% of the fuel in six cyclone boilers, including two units at the Rock River station, shown here.

2
Ohio Edison burned whole tires successfully for 18 months in its 42-MW pulverized-coal boiler in Toronto, Ohio.

3
Shredded tires are ready for burning at the Big Stone plant in Milbank, South Dakota. Jointly owned by Otter Tail Power, Northwestern Public Service Company, and Montana-Dakota Utilities, the 415-MW facility has been using tires as a supplemental fuel since 1990.

4
Shredded tires are conveyed into Illinois Power's Baldwin plant, where they will feed two 560-MW cyclone boilers. The utility has used tires for up to 2% of the fuel at these units since early this year.

5
This 26-MW plant in Sterling, Connecticut, is totally fueled by scrap tires, consuming about 10 million tires annually. Power from the plant, one of only three dedicated tire-burning plants in the country, is sold to Connecticut Light & Power. CMS Generation—a subsidiary of CMS Energy, the holding company of Consumers Power Company—owns a 50% share in the plant.

making the Toronto plant amenable to whole-tire burning included the boiler's wet-bottom design and its high operating temperature (about 3200°F). Because of the wet-bottom design, unburned tires were allowed to fall into the pool of molten slag in the bottom of the furnace, where they stayed as long as necessary to ensure complete combustion.

Getting the pulverized-coal boiler to accept whole tires took some significant modifications to the fuel-feeding system. The utility designed a tire delivery system complete with a conveyor and a lock hopper to drop the tires into the boiler at precalculated intervals. In a four-day test in the spring of 1990, the utility burned a fuel mix containing up to 20% tires—one tire every 10 seconds. At this mix, researchers recorded a 36% reduction in NO_x emissions, a 28% reduction in particulates, and a 14% reduction in SO_2. To top it off, says Szempruch, "we found that cofiring 20% tires in a nonreheat unit makes the heat rate about as good as that in a reheat unit."

Another successful approach to burning tires in coal-fired power plants is the use of fluidized-bed combustion (FBC) technology. Independent power producers, electric utilities, and others use FBC boilers to incinerate low-grade liquid- and solid-waste fuels; typically coal is the primary fuel. In this type of boiler, hot air causes particles of fuel and limestone to mix together in a turbulent, burning bed. As with most other coal-fired plants, bead wire from the tires must be removed before firing in an FBC unit, since the wire can accumulate in the lower portion of the bed and cause problems like bed defluidization or even a lengthy outage.

According to an EPRI report released in 1993, scrap tires have the highest energy content of all the alternative fuels considered for FBC boilers, including municipal solid waste, biomass, and sewage sludge. The report notes that for tire burning, FBC units should be designed with long furnace gas residence times, an overfire or secondary air system, and fly ash injection to ensure complete combustion. McGowin of EPRI notes that only a few fluidized-bed units have been built with tires in mind; one is a 20-MW unit run by Manitowoc Public Utilities in Wisconsin, which cofires tire chips and petroleum coke.

Infrastructure issues

The technical challenge of getting tires to burn well in coal-fired boilers is just half the battle. The costs related to fuel supply and preparation can either make or break a project. Utilities can opt to accept whole tires (and in many cases receive a tipping fee) and shred the tires themselves, or they can hire a contractor to supply them with shredded tires, ready for firing. McGowin notes that utilities that choose to hire a contractor should be sure to negotiate a low delivered cost on the fuel, since the contractor collecting the tires receives the tipping fee.

Most of the utilities cofiring tires opt to have chipped fuel delivered to their boilers. Illinois Power has hired a vendor, Waste Recovery Inc., to collect the tires, shred them to the utility's specifications, and deliver them to the tire-burning plant. Going one step further, the utility's five-year agreement with Waste Recovery specifies that the vendor is responsible for keeping the on-site storage, delivery, and feed systems running smoothly. "This plant is his cash register," says David Stopek of Illinois Power. "For him to get paid, this thing has to keep running. If something goes wrong, he has to fix it. We provide no extra people." Waste Recovery also provides the hardware needed for on-site fuel handling and feeding. Illinois Power estimates that it will save about $670,000 annually by burning roughly 7.5 million tires in its two cyclone boilers, reducing annual coal consumption by about 80,000 tons and SO_2 emissions by about 3200 tons.

WP&L uses different approaches at different facilities. One plant (the first one to cofire tire chips) has its own shredding facility, while a vendor delivers ready-to-fire tire chips to the other two tire-burning plants. Bob Newell says state-sponsored financial incentives played an important role in WP&L's decision to pursue the use of tires. In fact, a grant from the Wisconsin Department of Natural Resources paid for temporary tire-derived-fuel-handling facilities and flue gas testing during the initial test firing. Northern States Power Company and Manitowoc Public Utilities have received similar grants. In addition, since 1990, Wisconsin has offered $20 per ton for waste tires used in boilers for energy recovery. And just this year the state adopted a program that offers individuals or businesses that process tires an additional $20 per ton. Now a utility that both processes tires and uses them in its boilers can receive $40 per ton.

Ron May

Wisconsin's incentive program, which was adopted to rid the state of its waste tire overload, ends in 1996. According to Paul Koziar, manager of the waste tire program for the Wisconsin Department of Natural Resources, the incentives are intended only as seed money to help cover the initial capital investments and early operating expenses related to tire burning. Before Wisconsin instituted its incentive program, only about 15% of the state's scrap tires were used, and only a small amount went for energy production. Today, however, all of the 4 million to 5 million scrap tires generated annually are being put to productive use, and another 1 million to 2 million are being pulled from the scrap heap. In fact, more than 90% of the state's tire stockpiles are now cleaned up. According to Koziar, roughly 95% of the scrap tires used every year become fuel.

Wisconsin is not the only state encouraging the use of scrap tires. According to the Scrap Tire Management Council, 48 states have scrap tire regulations and 30–35 of them offer some sort of financial incentive. The program offered through the Illinois Department of Commerce and Community Affairs is widely recognized—along with Wisconsin's—as among the most aggressive in the country. The state of Illinois offers grants and loans to encourage the use of tires for fuel, including funding to help suppliers of tire-derived fuels establish their businesses. Utilities and others have relied on this money to conduct test burns and to purchase equipment for tire-burning plants. For instance, Illinois Power received $457,000 from the state, which went toward the purchase of a fuel-handling system and slag-cleaning equipment.

According to Alan Justice, manager of the state's Used Tire Recovery Program, by the end of the year Illinois will have enough fuel-burning capacity on-line to use more than the 12 million tires generated annually in the state, making the state a net importer of scrap tires. (Each year a small number of tires from the state's stockpile of several million are also used.) The state's other tire consumers include cement kilns and a new dedicated tire-burning facility to be operated by an independent power producer—the third such plant in the country.

Such high levels of tire consumption raise the question of whether there will be enough tires to go around if the utility industry takes full advantage of its opportunities for cofiring tire-derived fuel. "Supply is one of the major concerns for utilities, and rightly so," acknowledges Blumenthal of the Scrap Tire Management Council. "But so far, the regional supply has been more than sufficient to meet demand, and there are many areas of the country still ripe for tire use."

Besides, since the use of tire-derived fuel is restricted by boiler type, there are a limited number of facilities capable of tapping this resource. The sense among the utilities using tire-derived fuel is that those who manage to jump on the bandwagon quickly will benefit the most. "Using tire-derived fuel is a great way to make lots of tires go away—cost-effectively," says Stopek of Illinois Power, noting that his utility alone will be using up about 7.5 million scrap tires annually, or about half of those generated each year in the state. "After all, you can only make so many rubber doormats." ■

Further reading

Tire-Derived-Fuel Cofiring Test in a Pulverized-Coal Utility Boiler. Final report for RP2190-8, prepared by Iowa State University. December 1994. EPRI TR-103851.

Fluidized-Bed Combustion of Alternate Fuels. Final report for RP2190-6, prepared by Combustion Systems, Inc. December 1993. EPRI TR-100547.

Proceedings: Strategic Benefits of Biomass and Waste Fuels. December 1993. EPRI TR-103146.

Strategic Analysis of Biomass and Waste Fuels for Electric Power Generation. Final report for RP3295-2, prepared by Appel Consultants, Inc. December 1993. EPRI TR-102773.

Proceedings: 1991 Conference on Waste Tires as a Utility Fuel. September 1991. EPRI GS-7538.

Background information for this article was provided by Chuck McGowin of the Generation Group's Renewables & Hydro Business Unit.

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Repowering as a Competitive Strategy (page 6) was written by Taylor Moore, *Journal* senior feature writer, with information and assistance from three members of the Generation Group's Gas & New Coal Generation Business Unit.

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Stan Pace is manager of the business unit's strategic target on repowering, capacity enhancement, and new design. Earlier he was the Generation Group's international manager for fossil power plants. Pace joined EPRI in 1984 after six years with United Centrifugal Pumps of San Jose, California. He previously worked for Combustion Engineering for five years and still earlier was an instructor in the U.S. Navy Nuclear Power Program for four years. Pace received BS and MS degrees in mechanical engineering from Lehigh University.

John Scheibel manages the Gas & New Coal Generation Business Unit. Earlier he served as business and team manager for advanced fossil power systems and as a project manager for fossil plant performance. Scheibel came to EPRI in 1983 after six years at Combustion Engineering, where he worked for the power systems group in supercritical boiler R&D and computer-aided engineering. Before that, he was a power plant design engineer with Sargent & Lundy. Scheibel received BS and MS degrees in mechanical engineering from the University of Illinois. ■

Live Work (page 14) was written by Perry Garfinkel, science writer, with assistance from **Paul Lyons** of the Power Delivery Group. Lyons is a manager for overhead transmission lines in the Transmission Business Unit. Before joining EPRI in 1982, he was a senior project engineer at General Dynamics Corporation, where he worked for 16 years in the field of aircraft and spacecraft structural dynamics. Earlier he was an engineering analyst on the Apollo program for the National Aeronautics and Space Administration. He has a BS in aeronautical and astronautical engineering and an MS in structures and structural dynamics from Ohio State University. ■

A New Era for Fossil Power Plant Simulators (page 20) was written by science writer Steve Hoffman with assistance from **Roy Fray** of EPRI's Fossil Power Plants Business Unit. Fray joined the Institute in 1992 to work on the development and enhancement of plant simulator technology. He previously managed projects in that field for five years at Science Applications International Corporation. Before that, he was with Pacific Gas and Electric Company for 17 years, working on quality control, risk assessment, and dynamic simulation for both nuclear and fossil plants. Fray holds a BS in mechanical engineering from California State University, Fresno, and an ME in the same field from the University of California, Davis. ■

Tapping the Tire Pile (page 28) was written by Leslie Lamarre, *Journal* senior feature writer, with background information from **Chuck McGowin** of the Generation Group. McGowin is manager for biomass conversion in the Renewables & Hydro Business Unit. He came to EPRI in 1976 after seven years as a senior research engineer with Shell Development Company. He has a BA in applied science and a BS in chemical engineering from Lehigh University. He also has MS and PhD degrees in chemical engineering from the University of Pennsylvania. ■

Water Quality

EPRI-Utility Team Demonstrates New Method for Nitrate Removal

Because runoff from grazing land and fertilized farmland can leach into underground water supplies, the drinking water in some rural communities tends to have high nitrate levels. Such levels can be dangerous, bringing problems like methemoglobinemia, a disease that impairs the blood's ability to assimilate oxygen. Infants are especially susceptible to this disease, which puts them at risk of oxygen deprivation and a condition called blue baby.

Two technologies, based on ion exchange and reverse osmosis, already exist to remove nitrogen from drinking water. But both processes result in a waste stream with a high concentration of nitrogen, which makes disposal challenging. The reverse osmosis procedure has the added drawback of being expensive.

Researchers at the University of Colorado have developed a new process that relies on bacteria to biologically remove nitrogen from drinking water. This process, which is expected to be more cost-effective than existing methods, will be tested in a full-scale demonstration at the site of an existing well in Wiggins, Colorado. The system for the demonstration was under construction this summer, with startup planned for October.

The new technology relies on a commonly found group of bacteria called facultative anaerobic heterotrophs, which convert nitrogen in water to a gaseous form that dissipates. The conversion occurs inside what is referred to as the packed-tower component of the system. The water from the tower then runs through a slow sand filter, which removes the residual bacteria. According to Myron Jones, EPRI's manager for the project, the amount of residual bacteria is so small that it does not present a disposal problem.

The demonstration, which will continue for one year, will take place in the service territory of Morgan County Rural Electric Association, one of the groups funding the project along with EPRI. The other sponsors are Tri-State Generation and Transmission Association, the Colorado Department of Local Affairs, and the National Rural Electric Cooperative Association.

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

Automated Energy Control

World Financial Center Tries Out New RTP Controller

A new energy management system that automatically responds to real-time pricing (RTP) while maintaining indoor air quality came on-line at the World Financial Center in New York City in August. The critical component of this system is the RTP Controller, developed by Honeywell, which controls electricity use in the common indoor spaces serving the 8-million-square-foot complex, including the Winter Garden atrium and nearby shops and restaurants. These common areas alone have a peak electrical demand of 1.2 MW. Use of the controller is expected to lower that demand by 500 kW through the reduction of ventilation, lighting, and other loads.

Now offered by at least a dozen electric utilities in the country, RTP rates reflect how much it costs to generate and transmit electricity at different times during a given day. Typically, these rates vary by the hour and are announced a day in advance by the utility. This gives customers the option of reducing large discretionary loads during the most expensive periods.

According to Laurence Carmichael, EPRI's manager for the World Financial Center project, the complex has received RTP rates from its utility, Consolidated Edison Company of New York (another project sponsor), for about four years. But the center's previous energy management system offered no way to make an automated response to the special rates. As is common in such cases, the building operator had no detailed analyses or guidance indicating the appropriate load management strategy for maximizing cost savings. And in order to realize the full benefits of RTP, equipment control schedules have to be timed precisely, and hundreds of control parameters have to be adjusted several times a day—a task virtually impossible to accomplish manually.

Once commissioned, the RTP Controller receives rates from the utility and automatically optimizes electricity use on the basis of these rates, shedding or shifting specific electrical loads. The technology gives building operators the option of overriding any of its control decisions.

Carmichael notes that an important new element of the controller installed at the World Financial Center is its capacity to save energy while maintaining indoor air quality. This is due to a new sensor system that measures carbon dioxide and volatile organic compounds and integrates the results into the control strategy. If CO_2 and VOC levels are too high, the controller will increase ventilation to return them to safe levels. "The idea is to be extremely energy efficient without compromising indoor air quality," says Carmichael. The controller's performance will be monitored for two cooling seasons.

The RTP Controller, a commercial product, can be configured for other sites and is in fact already in use elsewhere. Its first application, at the Marriott Marquis Hotel in New York City in 1993, enabled the hotel to shed over 1 MW during high-rate periods—more than five times the load it could shed with manual control. Savings to the hotel were over $100,000 in the controller's first year on-line. Meanwhile, Consolidated Edison saved more than $180,000 through reduced peak demand and fuel costs. The newer version of the controller software, which incorporates the air quality element, has recently been installed at an office building and a factory in Baltimore and at a hospital in Atlanta.

Other sponsors of the World Financial Center project are the New York State Energy Research & Development Authority and the Empire State Electric Energy Research Corporation.

■ *For more information, contact Laurence Carmichael, (415) 855-7982.*

Energy Efficiency

Researchers Monitor Use of Office Equipment

In an effort to determine how consumers are responding to energy-efficient office equipment, a research team sponsored by EPRI and Consolidated Edison Company of New York is monitoring the use of such equipment. The contractor for this project, Architectural Energy Corporation, developed and installed the technology that is being used to monitor 20 conventional personal computers and 20 Energy Star PCs at an office building in New York City. Additional data will be gathered on Energy Star printers and copiers.

In order to carry the Energy Star logo, office equipment must meet certain energy efficiency criteria established by the U.S. Environmental Protection Agency. It must have the capability to enter a standby mode automatically after a period of inactivity, and in that mode, it must consume less than a specified amount of electricity; for instance, individual central processing units and monitors must each consume less than 30 W.

The EPA's Energy Star program, now about three years old, has encouraged some 700 manufacturers to produce thousands of products meeting the Energy Star criteria. These manufacturers represent approximately 85% of all PC and PC-monitor companies and over 90% of printer companies. In addition, several organizations, including the federal government, have instituted Energy Star purchasing policies.

The monitoring project, part of a larger effort by a consortium of EPRI member utilities and government agencies to encourage the use of energy-efficient office equipment, got under way this fall and will continue for four months. Researchers will monitor, for two months each, the use of conventional and Energy Star equipment. Then they will evaluate the results to determine the differences in demand and energy consumption between conventional and Energy Star PC technologies.

New users of Energy Star equipment will employ it without instruction for one month. They will then attend a workshop on its Energy Star features, after which their equipment use will be remonitored. Workshop attendees will also complete a user survey, developed by the Lawrence Berkeley National Laboratory, that is intended to determine how useful the workshop program was.

The survey results will indicate the potential effectiveness of educational programs in improving the energy savings of Energy Star equipment. EPRI member utilities interested in offering such programs will have access to these results, which will be published when the project is completed. The project will also document the energy-saving value of Energy Star equipment and will provide measured load shapes for various types of conventional and Energy Star equipment. Utilities are particularly interested in the details of such load shapes, since these plug loads are among the fastest-growing end uses in the commercial sector.

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

EPRI and ISA Sign Utility Training Partnership Agreement

An important step to advance the education and training of professionals in the electric power industry was taken recently by EPRI and ISA—the International Society for Measurement and Control (formerly the Instrument Society of America)—who agreed to sponsor a series of instrumentation and control (I&C) training programs. The collaboration responds to the competitive need to reduce O&M costs as the utility industry approaches deregulation. I&C plays a key role in enabling cost reductions.

"The importance of efficient operations dictates that electric utility personnel be properly trained," says Joe Weiss, the EPRI project manager. "This partnership, involving the utility industry's R&D arm and the I&C industry's standards body, creates a powerful force to provide the training needed to utilize both new and existing technologies." Tom Stout, ISA vice president of professional development, agrees: "Together, EPRI and ISA can clearly meet the education and training needs of the entire utility industry."


Digital control system display

The first programs in the EPRI-ISA alliance will cover control system analysis, control valve sizing, nuclear set points, and an overview of nuclear I&C. Most will be held at EPRI's I&C Center at the Tennessee Valley Authority's Kingston plant and at the ISA Training Center in Raleigh, North Carolina. ISA will provide continuing education credits.

The initial joint offering—a course on set points for nuclear safety-related instrumentation—will be held October 2–4, 1995, at the ISA/95 Training Program in New Orleans. The course will cover ISA's recommended practice for determining instrument trip set points in nuclear plants. To register, call ISA at (919) 549-8411.

A nonprofit organization with nearly 50,000 members around the world, ISA is a leading publisher, training provider, and organizer of conferences and exhibits in the field of measurement and control.

■ *For more information, contact Joe Weiss, (415) 855-2751.*

Eutectic Salt Cool Storage Evaluated

As a means of shifting air conditioning loads from on-peak to off-peak periods, cool storage offers a major load management opportunity for the utility industry, but significant market penetration of the technology hinges on reliable system design, installation, and operation. Cool storage systems that use eutectic salts as the storage medium rather than ice or chilled water are of interest for new and retrofit commercial and industrial applications because they can use chiller plants very similar to those employed in nonstorage systems. Moreover, the phase-change salts can store energy from the chilled water and avoid the loss of thermodynamic efficiency that may accompany ice storage.

EPRI recently sponsored a field evaluation of a eutectic salt cool storage system at a helicopter company facility in Arizona to demonstrate system viability and identify opportunities for improved design and operation. A project team led by the EPRI contractor, Dorgan Associates, instrumented the system to gather data on water temperatures, flows, and energy consumption over 16 months. The team compared the system's electricity use and utility costs (energy plus demand charges) with those of two modeled nonstorage approaches, one with heat exchangers for providing free cooling from cooling tower operation and one without such heat exchangers.

The on-peak demand of the eutectic salt cool storage system was lower than that of the modeled conventional systems by 692 kW, or 22%. Compared with the nonstorage system with heat exchangers, the cool storage system reduced peak energy consumption by 44% and utility costs by 17%. Its electrical energy consumption was equivalent to that of the nonstorage system without heat exchangers. Later modifications to the eutectic salt storage system to improve efficiency and reduce pumping energy requirements decreased auxiliary energy use by 10% and total on-peak energy use by 46%.

The project team identified additional savings that could be achieved at the Arizona site by modifying the chiller condenser water piping and control system to allow free cooling from the heat exchangers (without discharging storage) when their output is sufficient to meet the load. As at many other cool storage installations, the project's postcommissioning review by thermal storage experts has proven to be valuable. EPRI is now investigating new methods of encapsulating eutectic salts that will reduce the cost of such systems.

A technical report on the field evaluation project (TR-104942) is available from the EPRI Distribution Center, (510) 934-4212.

■ *For more information, contact Mukesh Khattar, (415) 855-2699.*

Ventilation Controller Field-Tested

Ventilation control systems are designed to protect indoor air quality in tight, energy-efficient homes by providing sufficient levels of fresh air to dilute indoor pollutants. But in the Pacific Northwest, where residential ventilation equipment is now required by code, many homeowners are not using the control systems because they are difficult to operate, a problem that has been traced to inadequate labeling and user interface design.

EPRI investigators recently field-tested a prototype ventilation control system in 16 homes to determine homeowner use and satisfaction. The field tests featured an improved version of a prototype residential ventilation controller (RVC) incorporating a carbon dioxide sensor. (A by-product of human occupation, CO_2 serves as a surrogate for indoor pollutants.) This project grew out of earlier work for EPRI by Honeywell to define the features and user interfaces of an RVC that would offer significant benefits over conventional controllers.

The modified system that was field-tested included a programmable RVC, a low-cost CO_2 monitor, and a homeowner's existing fan and associated switches. The project team selected 16 test sites from Bonneville Power Administration's service territory in Oregon, installed the control system at each site, and collected data over a four-month period. Following analysis, the team interviewed homeowners for feedback on the performance of the RVC and perceptions of its value.

After expressing dissatisfaction with their existing ventilation systems, homeowners reported that air quality significantly improved following installation of the prototype RVC. Data analysis revealed that the device reduced overall CO_2 concentration levels in homes by approximately 7%. Homeowners generally reported that the device was sensitive and easy to use. All participants elected to keep the RVC at the end of the field tests.

Prototype residential ventilation controller

The prototype controller features an adjustable duty cycle to control ventilation rate, programmable time-of-day scheduling, countdown timer override/purge to adjust CO_2 level, manual override with adjustable ventilation rate, and maximum-limit CO_2-based override (which enables the system to react indirectly to demand via the CO_2 sensor).

"Ventilation systems often remain unused because owners are not familiar with the systems and because operation guidelines are poor or nonexistent," notes John Kesselring, the EPRI project manager. "This work demonstrated that ease of use will increase customer acceptance of such systems." Additional EPRI work is under way to provide a more detailed assessment of a CO_2 controller for residential ventilation and indoor air quality management.

A report on the results of the field testing (TR-104890) is available from the EPRI Distribution Center, (510) 934-4212.

■ *For more information, contact John Kesselring, (415) 855-2902.*

Land and Water Quality

MOSES 2.0 Released for Beta Testing

by Ishwar Murarka, Environmental & Health Sciences Business Unit

The MOSES (Mineral Oil Spill Evaluation System) software was developed in 1990 because of concerns about impending regulations for electrical equipment containing oil—regulations involving the preparation and implementation of spill prevention, control, and countermeasures (SPCC) plans to protect surface waters. Based on a Monte Carlo routine, MOSES was designed to predict the potential for spills from oil-filled equipment to reach water bodies by overland flow. The code has been widely used by utilities in determining the need for SPCC plans for substations, evaluating mitigation measures, and designing new substations.

As a result of these applications, users have requested modifications to the code, including the ability to predict the spread of oil in water bodies, to prepare a draft SPCC plan that incorporates the results of MOSES simulations, and to predict whether any oil that might infiltrate beneath a substation could reach underlying groundwater. There was also interest in the addition of output schematics and graphs to show the potential spread of oil on land and on a water body—output that could be used in developing oil spill contingency plans and in determining appropriate cleanup equipment to have as a precaution.

In 1994, with tailored collaboration funding from the Utility Solid Waste Activities Group, EPRI initiated the development of MOSES-MP for the Microsoft Windows operating system. The new model will include version 2.0 of MOSES (with expanded capabilities as described below) and MP, which will determine whether any infiltrating oil can reach groundwater. MP is being developed by researchers at the University of Michigan, who also developed VALOR, an EPRI code that predicts the subsurface migration of oil. The MP code will interface with MOSES and will perform a one-dimensional simulation to reduce computation time. MOSES will prepare an output file of all the information it produces that is needed for the MP code—including spill volume and depth, spill duration, and the volume of oil that could infiltrate beneath the on-site gravel bed. MP will automatically access this file and combine it with input data entered directly into MP by the user.

Overview of MOSES 2.0

MOSES 2.0 covers the same processes modeled in the first version—volatilization, infiltration, containment by natural or man-made features, retention along paved or unpaved surfaces, and overland flow (Figure 1)—and adds processes necessary for predicting the spread of spilled oil in water bodies and for considering below-freezing weather conditions. There have been modifications in the mathematical representation of some of the processes; for example, the user can specify a given channel width or can have the code use data from actual spills to estimate the spread of oil on land.

Major changes were made to input requirements and to output. One input change involves spill volume distribution. In both versions of the code, the user selects the type of distribution—either uniform or exponential. (With a uniform distribution, the user specifies a lower limit and an upper limit for spill volume, and there is an equal probability that any value in this range will be selected by the Monte Carlo routine for a run. With an exponential distribution, the user supplies a mean volume value as well as the lower and upper limits, and larger spill volumes have a lower probability of being selected than smaller volumes.) Previously, MOSES let the user enter several distributions—one for up to 10 separate pieces of equipment. In MOSES 2.0, the user enters only one spill volume distribution. This approach makes the results much easier to interpret while it maintains the flexibility to evaluate either a specific spill (e.g., the rupture of a 5000-gallon transformer) or a scenario encompassing the range of spills likely at a given facility, from

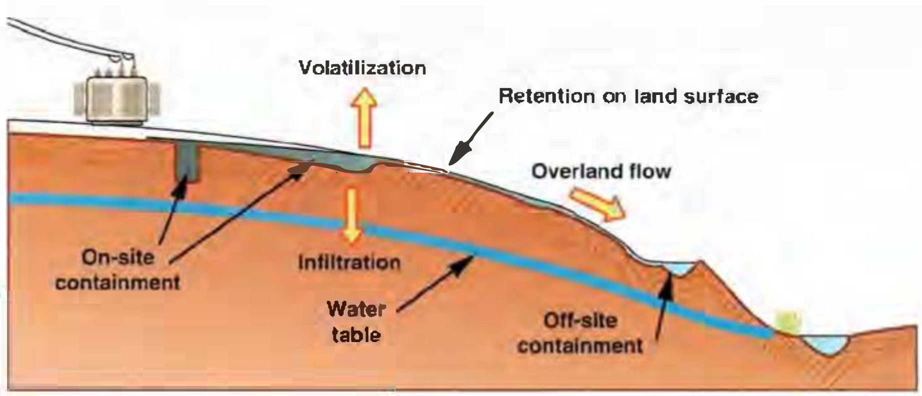


Figure 1 The MOSES code models various transport processes and containment options to predict whether oil spilled from electrical equipment will reach surface water. An enhanced version of the code, now in beta testing, also predicts the spread of spilled oil in water bodies and provides output necessary for determining whether oil will reach groundwater.

small leaks to the failure of all units due to fire or explosion.

Also, the user now has the option of dividing the off-site land area (i.e., the area lying outside the site's gravel bed and running to the riverbank) into six sections with different characteristics. Input has been simplified by providing data files for soil and vegetation characteristics. Both on-site and off-site land slope can be specified. Input for rainfall was changed to annual average rainfall and number of days with rain, since this information is easier to obtain. The code now provides such data for 102 cities across the United States. In addition, it includes typical fluid properties for mineral oil, various types of fuel oil, gasoline, and diesel fuel. For examining below-freezing conditions, the code includes representative properties of mineral oil at low temperatures and indicates the number of days below freezing at selected cities across the country.

Initially, MOSES presents results (the probability of a spill's remaining on-site and the probability of its reaching water) for a case that assumes that a spill occurs during each Monte Carlo run. After viewing these results, the user has the option of entering a site-specific probability that a spill will occur and then having MOSES recalculate the results. In that case, the new results—the joint probability that a spill will occur and will remain on-site and the joint probability that a spill will occur and will reach surface water—are shown in a second column next to the original values.

Other information calculated by MOSES 2.0 includes the following:

□ Maximum volume of spilled oil that reaches water body or drain

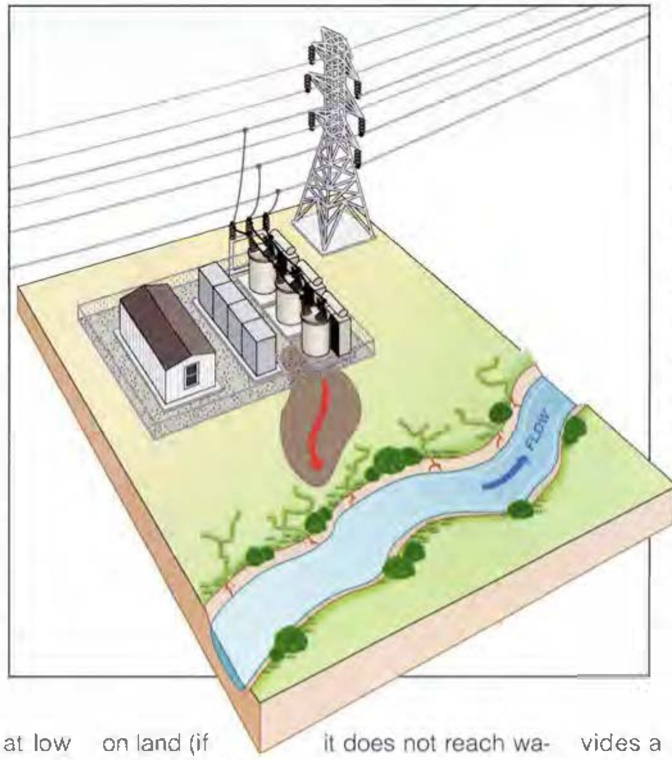
□ Area and depth of oil in river after 24 hours

□ Area of oil on lake after 24 hours (not yet operational)

□ Volume of oil retained on each off-site section, along with area and average thickness of oil layer

□ Maximum distance traveled by spilled oil on land (if it does not reach water body or drain)

Figure 2 MOSES 2.0 offers various new kinds of output—including a schematic showing the spread of the oil retained on land—that will be helpful to users in developing spill contingency plans.



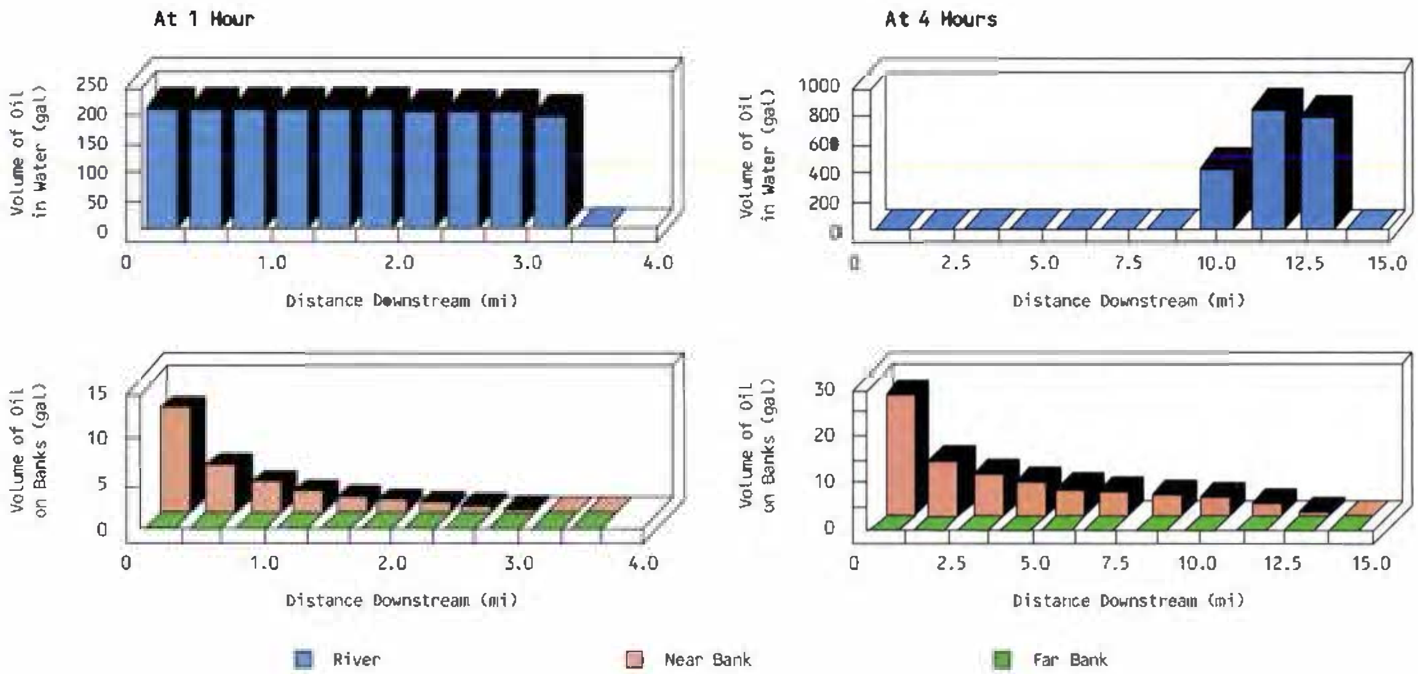
And new output graphics have been added. For example, there are graphs to show the volume of oil in the river and on the near and far banks at up to four different times, and there is a schematic showing the area of the spilled oil retained on land (Figure 2).

The model was set up so that the user can run a base case for a facility and then run a series of alternative scenarios—including a scenario with no man-made containment features and scenarios with various mitigation measures, such as additional gravel, on-site sumps, or retention basins. The code automatically runs all scenarios selected and displays the results along with those for the base case. The user can view key input parameters for both the base case and the alternative scenarios by means of the scenario output summary screen.

MOSES 2.0 has two new features to help users prepare SPCC plans. One is a draft SPCC plan text file editable by a word processor directly from MOSES. The other is SPCC Wizard, which provides a summary of simulation input and output for incorporation into the SPCC plan. Wizard will help the user determine if an SPCC plan is needed and will show how the simulation results would be used for the plan—for example, in identifying what cleanup equipment should be readily available in case a spill cleanup is required in the future. Thus the user can

ABSTRACT *The MOSES code, developed in 1990, was designed to predict the potential for spills from oil-filled electrical equipment to reach surface water. Its successful application led to requests that it be enhanced—for example, to include capabilities for predicting the spread of spilled oil in water bodies, for predicting whether oil infiltrating beneath a substation could reach underlying groundwater, and for preparing draft spill prevention, control, and countermeasures plans. The result is the new MOSES-MP code, which will combine MOSES 2.0—an enhanced version of the original code—with MP, a code for predicting whether spilled oil will reach groundwater. MOSES 2.0 is now in beta testing, and MP is in development.*

Figure 3 Predicted distribution of oil in a river and on riverbanks at 1 hour and 4 hours after a hypothetical spill. (Note that the scales in these graphs differ.) MOSES 2.0 will produce such results for up to four times specified by the user.



see the implications of the simulation results and can run additional cases, if necessary, before exiting the program. The information from SPCC Wizard will automatically be entered into the SPCC plan text file, and Wizard will be able to open a Windows-based word processor so that the file can be edited. The file will have blanks where site-specific information is to be entered.

Using MOSES 2.0

Together with MP, MOSES 2.0 will be helpful to utilities in evaluating whether SPCC plans are needed, deciding whether and to what extent preventive measures should be implemented, and developing substation designs in which containment needs are optimally incorporated. Results will also be useful in selecting possible cleanup strategies and deciding what kind of (and how much) cleanup equipment to maintain and where to situate it. The following two hypothetical cases—one in which oil was contained on land and one in which oil could reach a nearby river—illustrate applications of MOSES 2.0.

The first example examined the difference between using uniform and exponential spill volume distributions. The substation in the example had two small transformers of 700 and 1000 gallons, respectively, and the on-site gravel bed was about 1000 square feet. A creek was located 800 feet to the south, with a small drainage swale capable of retaining about 100 gallons of spilled oil. Two spill volume estimates were made: the first used a range from a small leak (100 gallons) to the complete failure of both units (1700 gallons) with a uniform distribution; the second used the same range but with an exponential distribution having a mean of 500 gallons. As expected, the probability of the oil's remaining on the gravel bed was higher with the exponential distribution than with the uniform distribution (0.976 versus 0.883). No spilled oil reached the surface water in either scenario.

The second example involved the upgrading of a substation to include a new, larger (5000-gallon) transformer. The MOSES analysis addressed the question of whether, in connection with the upgrading, a sump should be added to prevent oil from reaching the river in the event of a spill. The simulation results showed that on dry days the probability that spilled oil would reach the river was 0.0003, but for wet days it was 0.0339 without on-site containment (i.e., the sump). The predicted maximum volume reaching the river was about 2240 gallons, although the median volume was less than 500 gallons. For most runs, travel times to the river were between 20 and 50 minutes. Figure 3 shows the predicted distribution of spilled oil in the river at 1 and 4 hours after the hypothetical spill. In light of these results, various scenarios were run to evaluate mitigation options. Adding two retention basins of 1100 gallons each, one on-site and one off-site, was predicted to contain any spilled oil from the new transformer.

Computer requirements

Running MOSES-MP requires an IBM-compatible 486 or 386 personal computer with a math coprocessor, a color VGA or SVGA monitor, 8 MB of RAM, at least 7 MB of free space on the hard drive, and a mouse. The operating system must be either Windows 3.1 or Windows for Workgroups 3.11. The program is written in the FORTRAN and C languages, but compilers for these languages are not needed. Printing is controlled by the Windows Print Manager, allowing a wide variety of black-and-white or color printers to be used. The MOSES 2.0 beta version is available from EPRI on two disks, along with a beta testing guide. For information or a copy of the software, call Ishwar Murarka at EPRI, (415) 855-2150.

New Contracts

Project	Funding/Duration	Contractor/EPRI Project Manager
Customer Systems		
Inter-Control Center and Power Plant Communication (WO2568-37)	$126,200 12 months	ECC/*L. Carmichael*
Design and Analysis of Direct Load Control Programs (WO2980-45)	$2,056,700 109 months	Quantum Consulting/*R. Gillman*
Enhancing Commercial-Sector Competitiveness: Energy Use in Educational Buildings (WO3141-15)	$200,000 10 months	Hart, McMurphy & Parks/*K. Johnson*
Commercial Kitchen Ventilation Research (WO3851-2)	$730,200 27 months	International Facility Management Association/*W. Krill*
Electromagnetic Curing of Coatings (WO3878-2)	$75,000 7 months	Taratec Corp./*E. Eckhart*
Small Packaged Cool Storage Systems: Demonstration and Evaluation (WO3906-2)	$93,700 20 months	Powell Energy Products/*M. Khattar*
Application of Ultrasound in Textile Wet Processing, Phase 3 (WO4813-3)	$180,000 18 months	North Carolina State University/*A. Amarnath*
Commercialization of the Nonintrusive Load-Monitoring System (WO4833-1)	$200,000 21 months	Telog Instruments/*L. Carmichael*
Commercialization of the Nonintrusive Load-Monitoring System (WO4833-2)	$282,800 21 months	Plexus Research/*L. Carmichael*
Profit Manager: A Tool for Assessing the Profitability of Individual Customers or Customer Segments (WO4837-1)	$125,000 14 months	Electric Power Software/*P. Sioshansi*
Electric Vehicle Conductive Coupler Design and Development (WO4855-2)	$101,400 7 months	Walter Dorwin Teague Associates/*G. Purcell*
Food Service Sector Guide (WO4876-2)	$77,400 7 months	Hart, McMurphy & Parks/*W. Krill*
Non-CFC Chiller Retrofit Monitoring (WO4880-2)	$106,200 6 months	Energy Simulation Specialists/*W. Krill*
Environment		
Guidance Manual: Permit Limits From Aquatic Life Criteria (WO2377-10)	$126,000 8 months	EA Engineering, Science & Technology/*J. Mattice*
Field Measurements for Evaluating the Comanagement of High-Volume Combustion By-Products With Other Utility Wastes (WO4147-1)	$1,009,900 33 months	Battelle Pacific Northwest Laboratories/*I. Murarka*
Field Measurements for Evaluating the Comanagement of High-Volume Combustion By-Products With Other Utility Wastes (WO4147-2)	$828,500 27 months	Atlantic Environmental Services/*I. Murarka*
Mineral Insulating Oil Field and Laboratory Studies (WO4168-1)	$82,400 7 months	CH2M Hill/*I. Murarka*
Comparative Analysis of Magnetic Field Exposure Data on Electric Utility Workers (WO4306-6)	$85,400 12 months	EcoAnalysis/*L. Kheifets*
Thermal Desorption of Soil Recently Contaminated With Polycyclic Aromatic Hydrocarbons (WO9015-20)	$202,000 7 months	Barr Engineering Co./*L. Goldstein*
Florida Atmospheric Mercury Study Enhanced Data Analysis (WO9050-5)	$50,100 30 months	KBN Engineering & Applied Sciences/*D. Porcella*
Magnetic Field Shielding Case Studies (WO9074-1)	$510,200 33 months	Electric Research & Management/*R. Lordan*
Evaluation of a Pilot Curbside Water Treatment System for Manholes (WO9079-2)	$95,000 19 months	Hydroqual/*I. Murarka*
Emissions Management Methods for Utility Operations (WO9080-1)	$367,400 10 months	Decision Focus/*G. Hester*
Development of a Salt Marsh Mitigation Bank in the Barataria-Terrebonne National Estuary, Louisiana (WO9083-1)	$450,800 23 months	Louisiana State University/*J. Goodrich-Mahoney*
Treatability Study and Remedial Design for In Situ Stabilization at a Former Manufactured Gas Plant Site (WO9107-1)	$149,900 11 months	Atlantic Environmental Services/*I. Murarka*
North American Research Strategy for Tropospheric Ozone (NARSTO)–Northeast: NO_x Monitor Preparation (WO9108-2)	$172,400 9 months	Battelle Memorial Institute/*P. Mueller*
NARSTO-Northeast (WO9108-3)	$1,706,800 37 months	Radian Corp./*P. Mueller*
NARSTO-Northeast: Aircraft Measurements (WO9108-7)	$558,900 12 months	Sonoma Technology/*P. Mueller*
Southeastern Aerosol and Visibility Study (SEAVS): Physical and Optical Properties of Particles (WO9116-1)	$226,800 33 months	Aerosol Dynamics/*M. Allan*
SEAVS: Suspended-State Particle Composition (WO9116-2)	$182,200 33 months	Rutgers University/*P. Saxena*
SEAVS: Fine-Particle Concentrations of Water-Soluble Organics (WO9116-3)	$233,500 33 months	Stanford University/*M. Allan*
SEAVS: Particle and Gas Concentrations of Trace Substances (WO9116-4)	$104,100 33 months	Massachusetts Institute of Technology/*P. Saxena*
SEAVS: Human Perception of Scenes (WO9116-5)	$148,200 18 months	University of Southern California/*P. Saxena*
SEAVS: Fine-Particle and Vapor Concentrations of Acids and Neutralizing Substances (WO9116-6)	$153,000 31 months	Harvard University/*M. Allan*
Generation		
Generator Stator Winding Leaks Decision Advisor (WO2577-8)	$195,900 7 months	Iris Power Engineering/*J. Stein*
Nickel Speciation of Fly Ash From Oil-Fired Utility Plants (WO3177-28)	$55,000 8 months	University of Louisville/*P. Chu*
Pumped-Storage Diagnostic System, Phase 2 (WO3483-3)	$464,100 25 months	Mechanical Technology/*R. Colsher*
Inspection System for Reheater-Tubing Corrosion Pitting (WO3721-2)	$100,000 12 months	Karta Technology/*R. Tilley*
Operation and Maintenance Workstation (WO3782-4)	$1,462,600 48 months	Maintenance & Diagnostics/*R. Colsher*
Electric Motor Predictive Maintenance (WO3834-3)	$983,900 48 months	Maintenance & Diagnostics/*R. Colsher*
Turbine Efficiency Improvements (WO3849-3)	$819,900 32 months	Stress Technology/*T. McCloskey*
Evaluation of the Ultramax Optimization Method at HL&P's Parrish Plant (WO3982-1)	$104,500 7 months	Ultramax Corp./*S. Yunker*
Wind Turbine Performance Verification (WO4034-1)	$5,432,400 48 months	Central and South West Services/*E. Davis*
Guidelines for Hydro Turbine Fish Entrainment and Mortality Studies (WO4083-1)	$202,000 19 months	Alden Research Laboratory/*C. McGowin*
Development of Li_2MnO_3 as a Cathode Material for Molten Carbonate Fuel Cells (WO4084-1)	$100,000 13 months	Argonne National Laboratory/*R. Goldstein*
Numerical Analysis of Fossil Boilers for NO_x Compliance Planning (WO4088-1)	$415,600 23 months	Radian Corp./*C. Dene*

Project	Funding / Duration	Contractor / EPRI Project Manager
Strategic Assessment of Regional Coal Supply and Transportation Markets (WO4125-1)	$130,000 11 months	Fieldston Co / *J. Platt*
Wind Turbine Performance Verification (WO4155-1)	$4,380,000 77 months	Green Mountain Power Co / *E. Davis*
Nickel Speciation Field Sampling at Oil-Fired Power Plants (WO9028-18)	$78,800 10 months	Carnot / *P. Chu*
Evaluation of Concrete Containing Fly Ash With a High Carbon Content (WO9040-3)	$154,700 26 months	Southern Company Services / *D. Golden*
EPRICON Demonstration at the Brayton Point Station (WO9058-1)	$970,000 24 months	New England Power Service Co / *R. Altman*
Corrosion Studies for Low-NO_x Burner Technology (WO9060-2)	$117,700 15 months	Babcock & Wilcox Co / *W. Bakker*
Evaluation of Second-Generation Gas Reburning (WO9066-3)	$180,000 12 months	Energy and Environmental Research Corp / *A. Facchiano*

Nuclear Power

Project	Funding / Duration	Contractor / EPRI Project Manager
Interactive Software for Ultrasonic Training (WO3148-14)	$60,000 12 months	ABB Amdata / *J. Spanner*
Fission Product Pool Scrubbing Data and Modeling Assessment (WO3425-5)	$193,100 20 months	Battelle Ingenieurtechnik / *M. Merilo*
Photoelectrochemistry of Type 304 Stainless Steel (WO3468-10)	$100,200 27 months	University of Pittsburgh / *L. Nelson*
Large Electric Generator Maintenance Project (WO3814-5)	$133,500 14 months	Electro Mechanical Engineering Associates / *J. Sharkey*
SENTINEL: Safety-Oriented Advisor for Maintenance Planning (WO3868-3)	$150,000 15 months	ERIN Engineering and Research / *P. Kalra*
BWROG Full-Scale Emergency Core Cooling System Suction Strainer Test Program (WO4135-1)	$222,000 11 months	J. A. Jones Applied Research Co / *M. Downs*
ALWR Phase 3 Passive Plant Requirements (WO4160-3)	$150,000 72 months	Grove Engineering / *S. Gray*
Industry Alternatives to Regulatory Guide 1.154 (WO4175-2)	$72,000 8 months	Westinghouse Electric Corp / *R. Carter*
ProbeTrak: Prototype System for Acquiring Position Information During Manual Scanning (WO4248-1)	$223,900 12 months	Karta Technology / *T. Taylor*
Point Contact Transducer Technology for Monitoring Erosion and Corrosion in Piping Systems (WO4248-2)	$178,700 10 months	HD Laboratories / *T. Taylor*
Development of a Service Water Module for CHECWORKS (WO4528-1)	$50,000 8 months	Sargent & Lundy / *R. Mahini*
Developmental Testing of NDE Techniques for Structural Materials (WO5365-13)	$60,900 6 months	University of Michigan / *J. Lance*
BWR Vessel and Internals Project: Evaluation of Crack Growth in Internals (WOB301-9)	$99,500 6 months	Structural Integrity Associates / *R. Pathania*
Residual Stress Measurements of BWR Core Shroud Weldments (WOB301-10)	$88,600 10 months	J. A. Jones Applied Research Co / *R. Pathania*
Analysis of Nickel-Base Alloy Data (WOB301-13)	$55,200 7 months	Modeling and Computing Services / *L. Nelson*
BWR Vessel and Internals Project: Probabilistic Risk Assessment (WOB303-2)	$83,900 7 months	Science Applications International Corp / *W. Bilanin*
BWR Vessel and Internals Project: Repair Activities (WOB501-3)	$80,000 5 months	General Electric Co / *R. Thomas*
Repair of Reactor Internals With Underwater Welding (WOB501-6)	$144,000 12 months	J. A. Jones Applied Research Co / *R. Thomas*
Electrochemistry and Chemistry in a Heated Crevice (WOS522-6)	$175,800 12 months	Rockwell International Corp / *P. Millet*

Power Delivery

Project	Funding / Duration	Contractor / EPRI Project Manager
Aging of Extruded Dielectric Distribution Cable: Service Aging (WO2713-15)	$158,200 31 months	BICC Cables Corp / *B. Bernstein*
Slow Release of Fungicides for Wood Poles: Commercialization and Technology Transfer (WO2881-4)	$182,500 49 months	Engineering Data Management / *B. Bernstein*
Distributed Resources Strategic Market Assessment (WO3733-7)	$245,600 9 months	Applied Decision Analysis / *C. Smyser*
Evaluation of Room-Temperature-Vulcanized Coatings (WO3787-7)	$193,200 12 months	J. A. Jones Power Delivery / *A. Hirany*
Dynamic Voltage Restorer Demonstration (WO3924-6)	$425,000 22 months	Westinghouse Electric Corp / *A. Sundaram*
Nonceramic Insulators (WO4011-1)	$400,300 12 months	J. A. Jones Power Delivery / *M. Mastroianni*
Transmission Line Outage and Grounding Project (WO4085-2)	$58,100 7 months	J. A. Jones Power Delivery / *M. McCafferty*
Evaluation of Gases Generated by Heating and Burning of Cables (WO4142-1)	$466,400 37 months	Underwriters Laboratories / *R. Bernstein*
Development of Advanced Composite Materials for Utility Applications, Phase 2 (WO4159-1)	$125,400 6 months	Foster-Miller / *B. Bernstein*
Characterization of Nonceramic Insulator Aging for Transmission Line Applications up to 500 kV (WO7101-1)	$320,000 12 months	J. A. Jones Power Delivery / *M. Mastroianni*
HL&P Real-Time-Pricing Design and Assistance and C-VALU Beta Testing (WO7802-11)	$64,000 9 months	Laurits R. Christensen Associates / *C. Smyser*
COMAT Cable Oil Monitor and Tester (WO7924-3)	$323,500 14 months	Advanced Optical Controls / *T. Rodenbaugh*
Smart Software Interface/Expert System for Use on Portable Perfluorocarbon Tracer Gas Chromatographs (WO7928-4)	$123,100 8 months	Enertech Consultants / *T. Rodenbaugh*
Assessment of Extruded 345-kV Cable Technology (WO7929-1)	$52,500 21 months	Institut de Recherche d'Hydro-Québec / *D. Von Dollen*
Waltz Mill Data Acquisition System (WO7930-2)	$77,775 1 month	J. A. Jones Power Delivery / *D. Von Dollen*
Deep Cable Ampacities (WO7934-1)	$147,900 16 months	Power Delivery Consultants / *T. Rodenbaugh*

Strategic R&D

Project	Funding / Duration	Contractor / EPRI Project Manager
Exploratory Issues in Controller Synthesis for Critical Applications in the Nuclear and Fossil Power Industry (WO8016-10)	$143,800 36 months	University of Illinois, Urbana / *M. Perakis*
Development of an Advanced External Reference Electrode for Temperatures up to 400°C (WO8031-4)	$200,000 17 months	Pennsylvania State University / *B. Syrett*
Particle Dispersion in Three-Dimensional Free Shear Flows (WO8034-13)	$99,000 36 months	University of Southern California / *J. Maulbetsch*
Solid-Oxide Fuel Cell Business Assessment (WO8502-1)	$110,300 8 months	Resource Dynamics Corp / *K. Johnson*
Characterization of Sorbents for Removal of Vapor-Phase Mercury (WO8505-1)	$236,000 21 months	ADA Technologies / *R. Chang*
Investigations of Gas-Phase Mercury Reactions (WO8505-2)	$200,000 22 months	Radian Corp / *R. Chang*
Mercury Sorbent Evaluation (WO8505-3)	$185,700 8 months	University of North Dakota / *R. Chang*
Solid-Oxide Fuel Cells (WO8509-1)	$350,000 8 months	ZTEK Corp / *R. Goldstein*
Determination of Interfacial Crack Propagation Rates and Development of a Database on Mechanical Properties of Oxide Scales (WO9000-29)	$327,300 33 months	National Physical Laboratory / *B. Dooley*
Corrosion Fatigue of Water-Touched Components (WO9000-31)	$99,800 5 months	Aptech Engineering Services / *B. Dooley*
Ceramic Matrix Composites for Power-Generating Applications (WO9001-4)	$50,000 7 months	SRI International / *W. Bakker*
Development of Fiber-Optic Couplers for Welded-Tube Repair Technology for Steam Generators (WO9004-1)	$197,800 12 months	J. A. Jones Applied Research Co / *V. Viswanathan*
Welding Technology for the Repair of Power Plant Components (WO9004-2)	$459,900 35 months	J. A. Jones Applied Research Co / *V. Viswanathan*
Low-Pressure Rotor Rim Attachment Cracking: Survey of Utility Experience (WO9005-1)	$58,500 8 months	Structural Integrity Associates / *V. Viswanathan*

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). Domestic organizations not eligible for EPRI membership pay the listed price. Others should contact the Distribution Center for further information.

CUSTOMER SYSTEMS

Testing of a Heat Pump Clothes Dryer
TR-104235 Final Report (RP3417-4); $200
Contractor: Arthur D. Little, Inc.
Business Unit: Residential & Small Commercial
EPRI Project Manager: J. Kesselring

CLASSIFY Applications, Vol. 1: Gathering Information About Your Customers
TR-104568-V1 Final Report (RP4001-3); $200
Contractor: National Analysts, Inc.
Business Unit: Marketing Tools & DSM
EPRI Project Manager: T. Henneberger

Field Evaluation of a Eutectic Salt Cool Storage System
TR-104842 Final Report (RP3280-16); $50
Contractor: Dorgan Associates, Inc.
Business Unit: Residential & Small Commercial
EPRI Project Managers: R. Wendland, M. Khattar

Assessment of a Carbon Dioxide Controller for Residential Ventilation and Indoor Air Quality Management
TR-104970 Final Report (RP2417-20); $200
Contractor: GEOMET Technologies, Inc.
Business Unit: Residential & Small Commercial
EPRI Project Manager: J. Kesselring

Development of a Microwave Clothes Dryer: Interim Report III
TR-104988 Interim Report (WO3417-1); $200
Contractors: Thermo Energy Corp.; JG Microwave, Inc.
Business Unit: Residential & Small Commercial
EPRI Project Manager: J. Kesselring

The End-Use Technology Assessment Project: A Load-Shape Analysis of Ground-Source Heat Pumps and Good Cents Homes
TR-105004 (RP2342-8); $200
Contractor: Quantum Consulting, Inc.
Business Unit: Marketing Tools & DSM
EPRI Project Manager: P. Meagher

Survey on the Status of Integrated Resource Planning
TR-105107 Final Report (RP2982-22); $200
Contractor: Barakat & Chamberlin, Inc.
Business Unit: Marketing Tools & DSM
EPRI Project Manager: P. Sioshansi

Proceedings: Delivering Customer Value—7th National Demand-Side Management Conference
TR-105196 Proceedings (RP3084); $200
Contractors: Barakat & Chamberlin, Inc.; Pacific Consulting Services
Business Unit: Marketing Tools & DSM
EPRI Project Manager: J. Bloom

ENVIRONMENT

Land Application of Coal Combustion By-Products: Use in Agriculture and Land Reclamation
TR-103298 Final Report (RP3270-1); $200
Contractor: Environmental Management Services
Business Unit: Environmental & Health Sciences
EPRI Project Manager: J. Goodrich-Mahoney

Large Granular Lymphocytic (LGL) Leukemia in Rats Exposed to 60-Hz Magnetic Fields: Preliminary Studies and Protocol
TR-104577 Interim Report (RP2965-16); $200
Contractor: Battelle Pacific Northwest Laboratories
Business Unit: Environmental & Health Sciences
EPRI Project Managers: C. Rafferty, K. Ebi

Investigation of the Risk Factors for Sporadically Occurring Legionnaires' Disease
TR-104770 Final Report (RP3266-1, -2, -90); $200
Contractor: Ohio State University Research Foundation
Business Unit: Environmental & Health Sciences
EPRI Project Manager: J. Yager

Development of a Carbon Dioxide Pressure Technique for Chemical Stabilization of Alkaline Clean Coal Technology (CCT) Ash
TR-104840 Final Report (RP2485-21); $200
Contractor: Wyoming Water Services Center, University of Wyoming
Business Unit: Environmental & Health Sciences
EPRI Project Manager: J. Goodrich-Mahoney

Environmental Performance Assessment of Coal Combustion By-Product Use Sites: Road Construction Applications
TR-105127 Final Report (RP2796-1); $200
Contractor: Radian Corp.
Business Unit: Environmental & Health Sciences
EPRI Project Manager: D. McIntosh

GENERATION

BIOPOWER: Biomass and Waste-Fired Power Plant Performance and Cost Model, Version 1.0
TR-102774 Final Report (RP3295-2); license required
Contractor: Appel Consultants, Inc.
Business Unit: Renewables & Hydro
EPRI Project Manager: C. McGowin

Production and Testing of Lightweight Aggregates From Coal Gasification Slags
TR-103612 Final Report (RP1459-26); $200
Contractor: Praxis Engineers, Inc.
Business Unit: Advanced Fossil Power Systems
EPRI Project Manager: M. Epstein

Options for Increasing SO_2 Removal and Improving the Water Balance at Hoosier Energy's Merom Station, Vols. 1–3
TR-103923-V1–V3 Final Report (RP1031-19); $10,000 for set
Contractor: Radian Corp.
Business Unit: Environmental Control
EPRI Project Managers: D. Owens, R. Moser

1994 EPRI Heat-Rate Improvement Conference, Vols. 1–4
TR-104241-V1–V4 (RP1711-13); $1000
Contractor: Encor-America, Inc.
Business Unit: Fossil Power Plants
EPRI Project Manager: E. Petrill

Field Chemical Emissions Monitoring (FCEM) Generic Sampling and Analytical Plan
TR-104869 Final Report (RP3177-1); $200
Contractor: Radian Corp.
Business Unit: Environmental Control
EPRI Project Managers: B. Nott, P. Chu, W. Chow

Benefits and Detriments of Deploying Genetically Engineered Woody Biomass Crops
TR-104896 Final Report (RP3407); $10,000
Contractor: Bruce E. Haissig Co.
Business Unit: Renewables & Hydro
EPRI Project Manager: J. Turnbull

Proceedings: Effects of Coal Quality on Power Plants—Fourth International Conference
TR-104982 Proceedings (RP2256-8); $10,000
Contractor: Reaction Engineering International
Business Unit: Fossil Power Plants
EPRI Project Manager: A. Mehta

Operating Practices Guidebook (OPG)
TR-105102 Final Report (WO2831); $10,000
Contractor: Strategic Power Systems, Inc.
Business Unit: Fossil Power Plants
EPRI Project Manager: R. Frischmuth

Advanced Coal Feeder Tests at Sunbury Station
TR-105290 Final Report (RP1400-22); $10,000
Contractor: CQ Inc.
Business Unit: Fossil Power Plants
EPRI Project Manager: D. O'Connor

Proceedings: 1995 EPRI/GRI/DOE/PG&E Small Gas Turbines for Distributed Generation Workshop, Vols. 1 and 2
TR-105293-V1, TR-105293-V2 Proceedings (RP1677); $200 each volume
Contractors: George Hay; Sargent & Lundy
Business Unit: Advanced Fossil Power Systems
EPRI Project Managers: A. Cohn, D. Rastler

NUCLEAR POWER

Guidelines for Development of In-Cabinet Seismic Demand for Devices Mounted in Electrical Cabinets
NP-7146-SL-R1 (RP2925-7); license required
Contractor: Stevenson & Associates, Inc.
Business Unit: Nuclear Power
EPRI Project Manager: R. Kassawara

Guidelines for the Verification and Validation of Expert System Software and Conventional Software, Vols. 1–8
TR-103331-V1–V8 Final Report (RP3093-1); $200 each volume
Contractor: Science Applications International Corp.
Business Unit: Nuclear Power
EPRI Project Manager: J. Naser

Turbulence and Fluidelastic Excitation of a U-Tube Bundle
TR-103503 Final Report (RPS410-5); $200,000
Contractor: ABB Combustion Engineering, Inc.
Business Unit: Nuclear Power
EPRI Project Manager: D. Steininger

Alloy 690 Qualification: Corrosion Under Prototypic Heat Flux and Temperature Conditions
TR-104064 Final Report (RPS408-6); $500
Contractor: Westinghouse Electric Corp.
Business Unit: Nuclear Power
EPRI Project Manager: A. McIlree

Evaluation of Shielding Analysis Methods in Spent Fuel Cask Environments
TR-104329 Final Report (RP3290-2); $200
Contractor: Oak Ridge National Laboratory
Business Unit: Nuclear Power
EPRI Project Manager: R. Lambert

Calvert Cliffs Nuclear Power Plant Life Cycle Management/License Renewal Program: Reactor Pressure Vessel Evaluation
TR-104509 Final Report (RP3343-1); $5000
Contractors: Baltimore Gas and Electric Co.; Failure Analysis Associates, Inc.; Grove Engineering, Inc.
Business Unit: Nuclear Power
EPRI Project Manager: J. Carey

EPRI Fatigue Management Handbook, Vols. 1–4
TR-104534-V1–V4 Computer Manual (RP3321-1); license required
Contractor: Structural Integrity Associates, Inc.
Business Unit: Nuclear Power
EPRI Project Manager: S. Gosselin

Calvert Cliffs Nuclear Power Plant Life Cycle Management/License Renewal Program: Nuclear Plant Asset Management Case Study
TR-104615 Final Report (RP3343-15); $5000
Contractors: Baltimore Gas and Electric Co.; Janus Management Associates, Inc.
Business Unit: Nuclear Power
EPRI Project Manager: J. Carey

Operating Nuclear Power Plant Fatigue Assessments
TR-104691 Final Report (RP3321); $500
Business Unit: Nuclear Power
EPRI Project Manager: S. Gosselin

Utility Activities for Nuclear Power Plant Life Cycle Management and License Renewal
TR-104751 Final Report (RP2643-35); $5000
Contractor: Grove Engineering, Inc.
Business Unit: Nuclear Power
EPRI Project Manager: J. Carey

Decommissioning Economic Risk Advisor: DERAD Version 1.0 User's Manual
TR-104785 Final Report (RP3171-4); $20,000
Contractor: Decision Focus Inc.
Business Unit: Nuclear Power
EPRI Project Manager: C. Wood

PWR Primary-to-Secondary Leak Guidelines
TR-104788 Final Report (RPS550); $200
Contractor: PWR Primary-to-Secondary Leak Guidelines Committee
Business Unit: Nuclear Power
EPRI Project Manager: R. Thomas

Generic Seismic Technical Evaluations of Replacement Items for Nuclear Power Plants
TR-104871 Final Report (RP3186-31); $25,000
Contractor: EQE, Inc.
Business Unit: Nuclear Power
EPRI Project Manager: L. Loflin

Use of Flaw Aspect Ratios for Pressurized Thermal Shock Evaluations
TR-104894 Final Report (RP3757-3); $200
Contractor: Sartrex Corp.
Business Unit: Nuclear Power
EPRI Project Manager: R. Carter

Users Manual: WASTECOST DAW Module, Version 1.0
TR-104926 Final Report (RP2412); $10,000
Contractors: Management Resource International; Nosh Productions, Inc.
Business Unit: Nuclear Power
EPRI Project Manager: C. Hornibrook

Stress Corrosion Cracking of Alloys 600 and 182 in BWRs
TR-104972-V1–V3 Interim Report (RP2293-1, RPC101-21); license required
Contractor: ABB Atom AB
Business Unit: Nuclear Power
EPRI Project Manager: J. Nelson

Axial Cracking Phenomena in Burnable Poison Rods
TR-104979 Final Report (RP3609-3); $20,000
Contractor: ABB Combustion Engineering Nuclear Operations
Business Unit: Nuclear Power
EPRI Project Manager: B. Cheng

The Status of Nuclear Industry Cost Beneficial Licensing Actions (CBLA) Activities
TR-104987 Final Report (TC3719-3); $200
Contractor: Alan M. Ross, Consultant
Business Unit: Nuclear Power
EPRI Project Manager: F. Rahn

Proceedings: 1994 ASME/EPRI Radwaste Workshop
TR-105133 Proceedings (RP2414); $200
Contractor: Paul Williams & Associates
Business Unit: Nuclear Power
EPRI Project Manager: C. Hornibrook

Proceedings: 1994 EPRI International Low Level Waste Conference
TR-105134 Proceedings (RP2414); $200
Contractor: Paul Williams & Associates
Business Unit: Nuclear Power
EPRI Project Manager: C. Hornibrook

User's Guide for Steam Generator Analysis Package: SGAP Version 1.0
TR-105253 Final Report (RPS415-2, RPS541-1); license required
Business Unit: Nuclear Power
EPRI Project Manager: G. Srikantiah

POWER DELIVERY

Assessment and Inspection Methods (AIM) Field Experiment, Vols. 1 and 2
TR-104449-V1, TR-104449-V2 Final Report (RP3621-1); $5000 for set
Contractor: Engineering Data Management, Inc.
Business Unit: Transmission
EPRI Project Manager: P. Lyons

Conductor Wind Loading: Results of EPRI Field Validation Studies
TR-104480 Final Report (RP3748); $5000
Contractor: Sverdrup Technology—TLMRC
Business Unit: Transmission
EPRI Project Manager: P. Lyons

Low-Voltage Secondary Network Cable Reliability Study
TR-104863 Final Report (RP3127-4); $5000
Contractors: University of Connecticut; Hubbell/Kerite Co., Inc.
Business Unit: Distribution
EPRI Project Manager: B. Bernstein

Switching Transient Effects on High-Voltage Current Transformers
TR-104961 Final Report (RP3320-1); $5000
Contractor: BDM Federal, Inc.
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: S. Lindgren

Flow-Induced Electrification of Liquid-Insulated Electrical Equipment
TR-104973 Final Report (RP3334-1); $5000
Contractor: Massachusetts Institute of Technology
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: S. Lindgren

Power Transformer Tank Rupture: Risk Assessment and Mitigation
TR-104994 Final Report (RP3212-1); $5000
Contractor: Westinghouse Electric Corp.
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: S. Lindgren

Experimental Study of Undrained Behavior of Drilled Shafts During Static and Cyclic Inclined Loading
TR-104999 (RP1493-4); $5000
Contractor: Cornell University
Business Unit: Transmission
EPRI Project Manager: A. Hirany

Reliability-Based Design of Foundations for Transmission Line Structures
TR-105000 (RP1493-4); $5000
Contractor: Cornell University
Business Unit: Transmission
EPRI Project Manager: A. Hirany

Hybrid Filters for Power System Harmonics
TR-105009 Final Report (RP1426-5); $5000
Contractor: University of Minnesota
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: A. Edris

IntellCAD: Software to Enhance CAD and Database Management Systems for Power System Operations
TR-105080 Final Report (RP3573-14); $5000
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: D. Sobajic

Prototype On-Line Dynamic Security Assessment (DSA) Program: User's Guide
TR-105082 Final Report (RP3103-2); $5000
Contractor: ABB Systems Control
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: P. Hirsch

Power System Transient Stability Assessment Using Vector Processor Supercomputers
TR-105166 Final Report (RP8010-20); $5000
Contractor: University of Minnesota
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: D. Maratukulam

STRATEGIC R&D

Reference Manual for On-Line Monitoring of Water Chemistry and Corrosion
TR-104928 (RP8044); $400
Business Unit: Strategic R&D
EPRI Project Manager: B. Syrett

Structural Change in the Coal Industry: Coal Industry Concentration Trends, 1970–1994
TR-105026 Final Report (RP3440-5); $195
Contractor: Energy Ventures Analysis, Inc.
Business Unit: Strategic R&D
EPRI Project Manager: J. Platt

Study of Multi-Element Diffusion Coatings
TR-105062 Final Report (RP2742-1); $200
Contractors: University of Pittsburgh, Department of Metallurgical and Materials Engineering; Lockheed Missiles & Space Co., Inc.
Business Unit: Strategic R&D
EPRI Project Manager: W. Bakker

Proceedings: Shape Memory Alloys for Power Systems
TR-105072 Proceedings (RP9000); $200
Contractor: Memry Corp.
Business Unit: Strategic R&D
EPRI Project Manager: V. Viswanathan

Development of Advanced High-Performance Thermoplastic Coatings for Distribution Cable Moisture Protection
TR-105073 Final Report (RP8007-19); license required
Contractor: Foster-Miller, Inc.
Business Unit: Strategic R&D
EPRI Project Manager: B. Bernstein

New Computer Software

Orders for EPRI-developed software should be directed to the Electric Power Software Center, 1930 Hi Line Drive, Dallas, Texas 75207; (800) 763-3772. EPRI members can receive, free of charge, software developed by the business units to which they subscribe. Others should contact EPRI's Licensing Office at (415) 855-2974.

ASAPP™: Accounting Software Application for Pollution Prevention
Version 1.1 (PC-DOS)
Contractor: Radian Corp.
Business Unit: Environmental Control
EPRI Project Manager: Mary McLearn

C²ALM: Control Center Advisor for Load Management
Version 1.0 (PC-DOS)
Contractor: TASC, Inc.
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: Ram Adapa

CLEAN: Comprehensive Least Emissions Analysis
Version 2.0 (PC-DOS)
Contractor: Science Applications International Corp.
Business Unit: Marketing Tools & DSM
EPRI Project Manager: Perry Sioshansi

Compact Simulator™
Version 1.0BA (PC-OS/2)
Contractor: TRAX Corp.
Business Unit: Fossil Power Plants
EPRI Project Manager: Roy Fray

Compact Simulator™
Version 1.0MI (PC-OS/2)
Contractor: TRAX Corp.
Business Unit: Fossil Power Plants
EPRI Project Manager: Roy Fray

Compact Simulator™
Version 1.0WE (PC-OS/2)
Contractor: TRAX Corp.
Business Unit: Fossil Power Plants
EPRI Project Manager: Roy Fray

EA Manager™: SO_2 Compliance and Emission Allowance Strategy Planning
Version 1.5 (PC-DOS)
Contractor: Decision Focus Inc.
Business Unit: Environmental & Health Sciences
EPRI Project Manager: Gordon Hester

Fatigue Management Handbook
Version 1.0 (PC-DOS)
Contractor: Nondestructive Evaluation Center
Business Unit: Nuclear Power
EPRI Project Manager: Steve Gosselin

HELM-PC: Hourly Electric Load Model
Version 2.1 (PC-DOS)
Contractor: ICF Resources, Inc.
Business Unit: Marketing Tools & DSM
EPRI Project Manager: Paul Meagher

MarketTREK™: Market Penetration Forecasting Tool
Version 2.0 (PC-DOS)
Contractor: Research Triangle Institute
Business Unit: Marketing Tools & DSM
EPRI Project Manager: Paul Meagher

MOV: Motor-Operated Valves
Version 1.0 (PC-DOS)
Contractor: MPR Associates
Business Unit: Nuclear Power
EPRI Project Manager: John Hosler

RateManager
Version 2.0 (PC-DOS)
Contractor: Electric Power Software
Business Unit: Marketing Tools & DSM
EPRI Project Manager: Perry Sioshansi

RETOU-WIN: Residential Response to Time-of-Use Rates
Version 1.01 (PC-DOS)
Contractor: Christensen Associates
Business Unit: Marketing Tools & DSM
EPRI Project Manager: Perry Sioshansi

SGWorkstation: System Grounding Workstation
Version 2.0 (PC-DOS)
Contractor: BSG Alliance/IT
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: Jerry Melcher

UTWorkstation: Underground Transmission Workstation
Version 2.0 (PC-DOS)
Contractors: Power Technologies, Inc.; BSG Alliance/IT
Business Unit: Transmission
EPRI Project Manager: Tom Rodenbaugh

WASTECOST DAW
Version 1.0 (PC-DOS)
Contractor: Management Resources
Business Unit: Nuclear Power
EPRI Project Manager: Carol Hornibrook

EPRI Events

NOVEMBER

1–3
PWR Plant Chemists Meeting
Orlando, Florida
Contact: Barbara James, (707) 823-5237

5–9
1995 Performance Measurement Workshop
Denver, Colorado
Contact: Lynn Stone, (214) 556-6529

6–8
Radiation Field Control Conference and Decontamination Seminar
Tampa, Florida
Contact: Lori Adams, (415) 855-8763

6–8
6th Conference on Decision Analysis for Utility Planning and Management
San Diego, California
Contact: Charmaine Glenn, (415) 926-9227

7–9
Distributed Control Systems Retrofit Workshop
Knoxville, Tennessee
Contact: Christine Lillie, (415) 855-2010

8–9
Control Coordination Between Power Plants and Energy Control Centers
Knoxville, Tennessee
Contact: Susan Bisetti, (415) 855-7919

8–10
Equipment Qualification Data Bank (EQDB) Annual Meeting
Tampa, Florida
Contact: Fran Rosch, (704) 547-6073

13–14
Transmission Line Outage Workshop
New Orleans, Louisiana
Contact: Mike McCafferty, (817) 439-5900

14–17
Motor Monitoring and Diagnostics
Palo Alto, California
Contact: John Niemkiewicz, (610) 595-8871

15–16
Opportunity Knocks: The Changing World of Energy Services
Palm Springs, California
Contact: June Appel, (610) 667-2160

28–30
1995 EPRI International Clean Water Conference
La Jolla, California
Contact: Christine Lillie, (415) 855-2010

28–30
Utility Motor and Generator Predictive Maintenance and Refurbishment
Orlando, Florida
Contact: Susan Bisetti, (415) 855-7919

28–December 1
Maintenance and Repair of Tubular Heat Transfer Equipment
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (610) 595-8871

DECEMBER

4–7
Reliability-Centered Maintenance
Newport Beach, California
Contact: Denise Wesalainen, (415) 855-2259

5–6
Vitrification of Low-Level Waste: The Process and Potential
San Antonio, Texas
Contact: Christine Lillie, (415) 855-2010

6–8
Meeting Customer Needs With Heat Pumps—1995
St. Louis, Missouri
Contact: Linda Nelson, (415) 855-2127

6–8
Polymer Technology Workshop
Palo Alto, California
Contact: Bruce Bernstein, (202) 293-7511

6–8
Seminar on Resource Planning in a Competitive Environment
Phoenix, Arizona
Contact: Elliot Boardman, (407) 361-0023

11–12
Transmission Line Grounding Workshop
Location to be announced
Contact: Mike McCafferty, (817) 439-5900

12–14
North American Electric Vehicle and Infrastructure Conference
Atlanta, Georgia
Contact: Lori Adams, (415) 855-8763

FEBRUARY 1996

5–7
Substation Equipment Diagnostics Conference IV
New Orleans, Louisiana
Contact: Denise Wesalainen, (415) 855-2259

20–21
Center for Materials Production Industrial Minerals Workshop
Ontario, California
Contact: Joe Goodwill, (412) 268-3435

29–March 1
1996 Power Delivery Issues Meeting
Location to be announced
Contact: Jon Ferguson, (817) 439-5900

MARCH

19–20
Managing for Biodiversity: Emerging Ideas for the Electric Utility Industry
Williamsburg, Virginia
Contact: Christine Lillie, (415) 855-2010

27–29
1996 Innovative Electricity Pricing
San Diego, California
Contact: Lori Adams, (415) 855-8763

APRIL

9–11
The Future of Power Delivery
Washington, D.C.
Contact: Lori Adams, (415) 855-8763

9–11
1996 Electric Food Service Symposium
Nashville, Tennessee
Contact: Susan Bisetti, (415) 855-7919

10–12
Pollution Prevention Seminar
Denver, Colorado
Contact: Linda Nelson, (415) 855-2127

MAY

8–10
CEM (Continuous Emissions Monitoring) Users Group Meeting
Kansas City, Missouri
Contact: Linda Nelson, (415) 855-2127

22–24
1996 Heat Rate Improvement Conference
Dallas, Texas
Contact: Susan Bisetti, (415) 855-7919

JUNE

11–13
Interaction of Non-Iron-Based Materials With Water and Steam
Piacenza, Italy
Contact: Linda Nelson, (415) 855-2127

17–19
6th International ISA POWID/EPRI Controls and Instrumentation Conference
Baltimore, Maryland
Contact: Lori Adams, (415) 855-8763

JULY

22–24
1996 International Low-Level-Waste Conference
New Orleans, Louisiana
Contact: Linda Nelson, (415) 855-2127

24–26
ASME/EPRI Radwaste Workshop
New Orleans, Louisiana
Contact: Linda Nelson, (415) 855-2127

29–August 1
Fossil Plant Maintenance Conference
Baltimore, Maryland
Contact: Lori Adams, (415) 855-8763

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