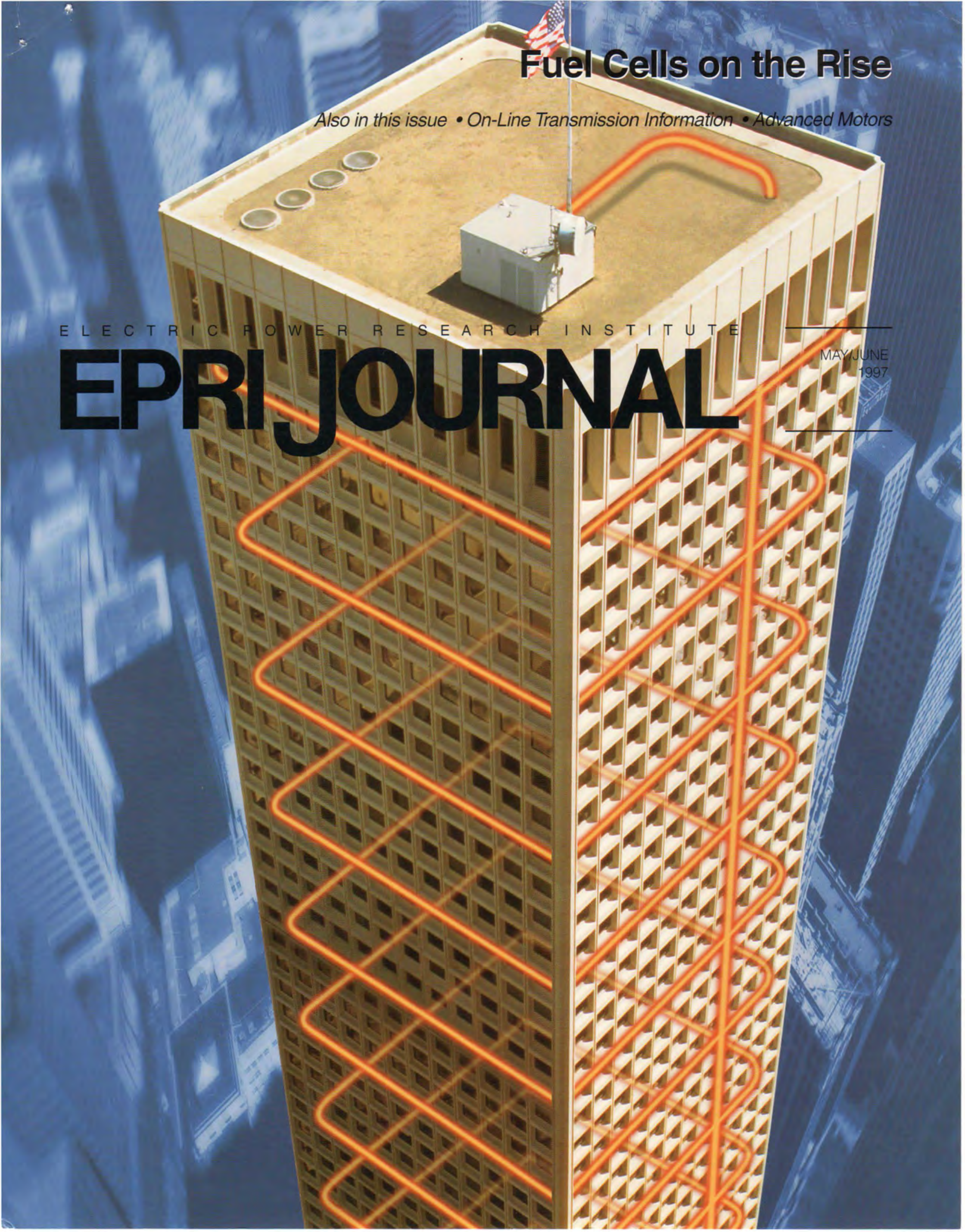
ELECTRIC POWER RESEARCH INSTITUTE

EPRI JOURNAL

MAY/JUNE 1997

Fuel Cells on the Rise

Also in this issue • On-Line Transmission Information • Advanced Motors



EPRI JOURNAL is published six times each year (January/February, March/April, May/June, July/August, September/October, November/December) by the Electric Power Research Institute.

EPRI was founded in 1972 by the nation's electric utilities to develop and manage a technology program for improving electric power production, distribution, and utilization.

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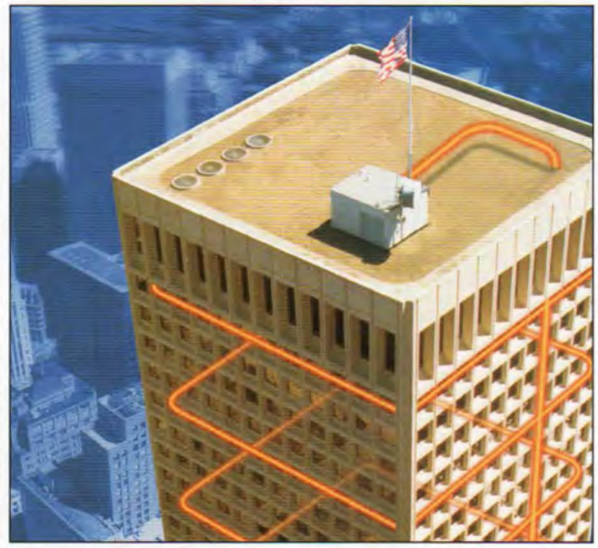
Cover: Grid-independent application on the customer's site is one possibility for a new generation of advanced fuel cells expected to hit the market within five years. (Photo by Weinberg & Clark)

EPRI JOURNAL

Volume 22, Number 3 May/June 1997



6 Fuel cells

COVER STORY

6 Market Potential High for Fuel Cells
As advanced, lower-cost fuel cells approach commercialization, planners are predicting substantial market opportunities in applications like distributed utility power, on-site customer generation, grid-independent power, and electric vehicles.

FEATURES

18 Deregulating in the Information Age
The electric power industry reached a major milestone under a tight deadline early this year with the launching of OASIS—a FERC-mandated, Internet-based system for buying and selling power transmission services.

26 The Written-Pole Revolution
The award-winning Written-Pole technology overcomes some fundamental drawbacks of conventional motors and generators to address critical needs of power customers, from cost-saving single-phase operation to supply of uninterruptible power.

18 OASIS

DEPARTMENTS

2 Products

4 Discovery

35 Contributors

36 Project Startups

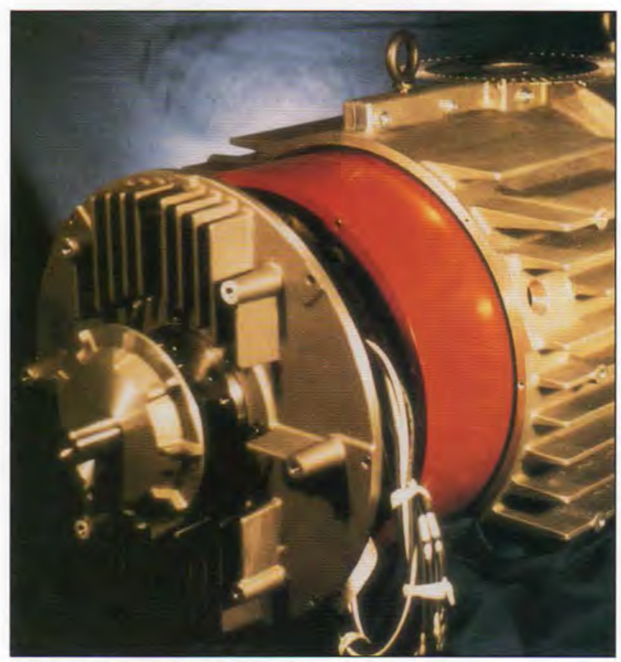
38 In the Field

LISTINGS

40 New Technical Reports

43 New Computer Software

44 EPRI Events



26 Written-Pole motors

PRODUCTS

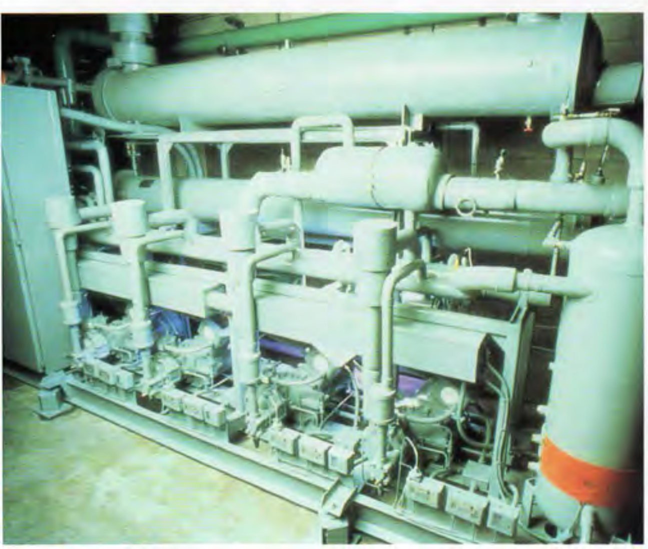
EPRI-sponsored deliverables now available to utilities and their customers

Electricity Book

EPRI developed this software tool to help power companies manage their business portfolios in an uncertain electricity market. The EPRI Electricity Book estimates the current market value of electric power resources and commitments (including options and futures), taking into account not only uncertainty in power and fuel markets but also the flexibilities (such as dispatchability) associated with various resources. The program will calculate value and risk exposure for each position or instrument in a portfolio and for the portfolio as a whole. Managers can use these results to help determine whether to add a new position or to close out or revise an existing position. They can also use the results to assess and manage the risk exposure of an existing or prospective business portfolio. *For more information, contact Art Altman, (415) 855-8740. To order, call the Electric Power Software Center, (800) 763-3772.*

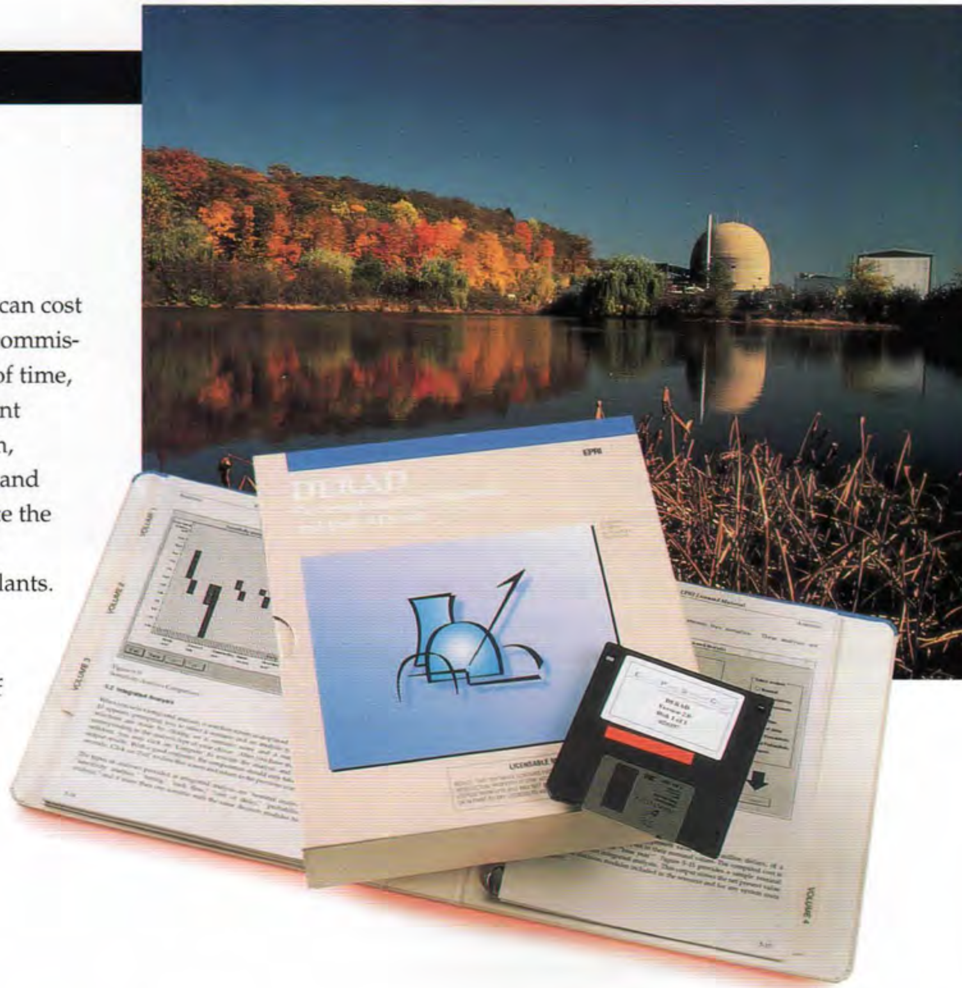
NIALMS

The Non-Intrusive Appliance Load-Monitoring System (NIALMS), a small electronic data recorder that fits between a residential customer's kilowatthour meter and the meter socket, determines the electricity being used by various appliances in a house and then transmits this information to the utility. The device makes it unnecessary for utility personnel to enter customers' homes to retrieve load-monitoring data. NIALMS can identify power consumption patterns for an entire house or for individual appliances (without the need to meter each appliance separately). It can also identify faulty appliances or abnormal energy use patterns. Utilities can use these data to improve customer satisfaction and pursue new business opportunities. *For more information, contact Larry Carmichael, (415) 855-7982. To order, call Nick Steo at Enetics Inc., (716) 924-5010.*



EcoCHILL

This award-winning air conditioning system is the first midsize chiller to use R-407C, a nonchlorine refrigerant. EcoCHILL is comparable in efficiency to many currently used chillers that employ ozone-destroying refrigerants containing chlorine, which the federal government is phasing out. The system uses off-the-shelf components, keeping repairs and routine maintenance easy, fast, and affordable. Other advantages include a single-path counterflow design for maximum heat exchanger performance; increased cooling capacity, thanks to a two-step process for subcooling; and variable-speed control of the cooling tower fan, which allows the system to operate very efficiently at part load. The first application of this environmentally friendly chiller—in the student union building at California State Polytechnic University in Pomona—won a technology award from the Orange County chapter of ASHRAE.
For more information, contact Wayne Krill, (415) 855-1033. To order, call Doug Scott at VaCom Technologies, (909) 392-6704.

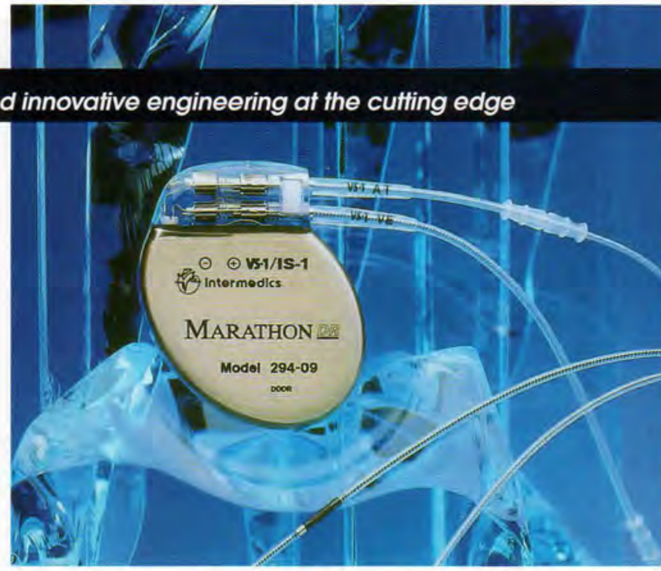


DERAD

Decommissioning a single nuclear power plant can cost hundreds of millions of dollars. Because the decommissioning process occurs over a sustained period of time, it is difficult to evaluate the financial commitment required. This expanded and upgraded program, Version 2.0 of the Decommissioning Economics and Risk Advisor (DERAD), can help utilities evaluate the costs and financial risks involved in alternative decommissioning scenarios for BWR and PWR plants. With DERAD, utilities can determine the most economical time to initiate decommissioning activities and even assess the financial impact of delaying a shutdown. The software package includes case studies to support DERAD use. *For more information, contact Chris Wood, (415) 855-2379. To order, call the Electric Power Software Center, (800) 763-3772.*

ProfitManager

The changes under way in the electric power industry are leading toward a more competitive, deregulated market that will offer customers the opportunity to shop around for an energy supplier. To prosper in this new environment, power companies must develop a good understanding of the profitability of serving their key customers and customer segments. That's why EPRI developed ProfitManager. A Windows-based software tool, ProfitManager guides users through profitability analyses with easy-to-use menus and forms. A power company can use this tool to systematically resolve critical business issues. For example, the company can determine the financial advantages of retaining existing customers and can identify what types of loads to attract or avoid and what types of services and rates to offer. *For more information, contact Paul Meagher, (415) 855-2420. To order, call the Electric Power Software Center, (800) 763-3772.*



COURTESY SULZER INTERMEDICS

Pacemakers and EMF

Currently about 115,000 cardiac pacemakers are implanted annually in the United States. These devices have saved countless lives by artificially stimulating diseased or damaged hearts when necessary, ensuring that they continue to beat in a stable rhythm. It has been known for some time that under certain circumstances, power-frequency electric and magnetic fields (EMF) can interfere with such implanted devices. For this reason, the American Conference of Governmental Industrial Hygienists (ACGIH), a private body that issues advisory guidelines for chemicals and physical agents in the workplace, has issued EMF exposure guidelines for workers with pacemakers. At the power frequency of 60 Hz, the guideline levels are 1 G for magnetic fields and 1 kV/m for electric fields.

In the late 1970s and early 1980s, EPRI conducted research on potential interference with pacemakers by 60-Hz electric and magnetic fields associated with overhead transmission lines and occupational environments. The results have helped utilities respond to public and employee concerns about possible EMF interference with cardiac pacemakers. Now, with the development of new, advanced pacemaker designs, the Institute has sponsored a fresh state-of-the-art review of the issue. The study, conducted by Dr. Antonio Sastre, is based on an extensive search of computerized literature databases, phone surveys of major U.S. manufacturers of implantable medical devices, and discussions with experts at the U.S. Food and Drug Administration.

COURTESY MEDTRONIC, INC.

Normally, the heart beats to the drum of its own natural pacemaker, the sinoatrial node, located in the right atrium. This node generates impulses that are conducted to the rest of the heart via specialized bundles of muscle cells, ensuring that the heart's atria and ventricles contract in an orderly fashion. As a result of disease processes and sometimes of normal aging, the sinoatrial node or the bundles that conduct the signals may fail to function properly.

Modern medical technology can often take over for an improperly functioning heart. Today's cardiac pacemaker is a highly sophisticated programmable device that delivers precisely timed electrical impulses that stimulate the heart to beat appropriately. Pacemakers of various designs are available, but recently the dual-chamber pacemaker has become widely used. In contrast to former models, which stimulated only the ventricles, the dual-chamber device stimulates both the atria and the ventricles in a way that results in a more natural beat.

The concern over EMF is that under certain circumstances, external fields can interfere with the pacemaker's ability to sense normal, endogenous electrical activity in the heart. Most modern pacemakers are designed to deal automatically with this problem, reverting to fixed-rate, or asynchronous, pacing when external fields interfere with their electronics' sensing capability. Reversion to asynchronous pacing is not considered hazardous and is, in fact, a life-preserving default feature of implanted pacemakers. However, with dual-chamber pacemakers, cases of inappropriate pacing before unit reversion to the asynchronous mode have been documented.

EPRI's review of EMF effects on pacemakers included an analysis of interference threshold levels. The study found that depending on manufacturer and design, the magnetic field threshold for pacemaker interference (including the possibility of inappropriate pacing) is in the range of 2 to 12 G; the electric field threshold was found to be about 1.5 kV/m for some of the newer—and more sensitive—dual-chamber units and above 2 kV/m for current or older ventricular units. Thus the ACGIH guidelines appear to be adequately protective of individuals who wear pacemakers. As well as can be determined, no pacemaker failures at the guideline levels have been documented.

■ *For more information, contact Rob Kavet, (415) 855-1061.*

Fingerprinting MGP Contaminants

Manufactured gas plant (MGP) sites are a legacy of the gaslight era, which began in the early 1800s. At that time, with natural gas not yet available, cities and towns used a crude reaction process to manufacture gas from coal for street lighting. By the 1950s, widespread electrification and the discovery of natural gas had brought gas manufacturing to a halt, and many of the MGP sites changed ownership and use. In the 1980s, environmental regulations focused attention on the coal tars and other residues at MGP sites and required site assessment and remediation. For the many electric utilities that evolved from the early gaslight companies, MGP sites have often become an environmental liability.

Determining who is responsible for a contaminated MGP site can be a complex matter—one involving current and former ownership not only of the site itself but sometimes of adjoining properties as well. Contaminant source identification is an important tool for resolving this issue, especially when two or more gas-manufacturing processes were used at a site, when the site was used for purposes other than MGP operations, or when the site is located adjacent to a manufacturing facility, gas station, chemical plant, or other potential source of contamination.

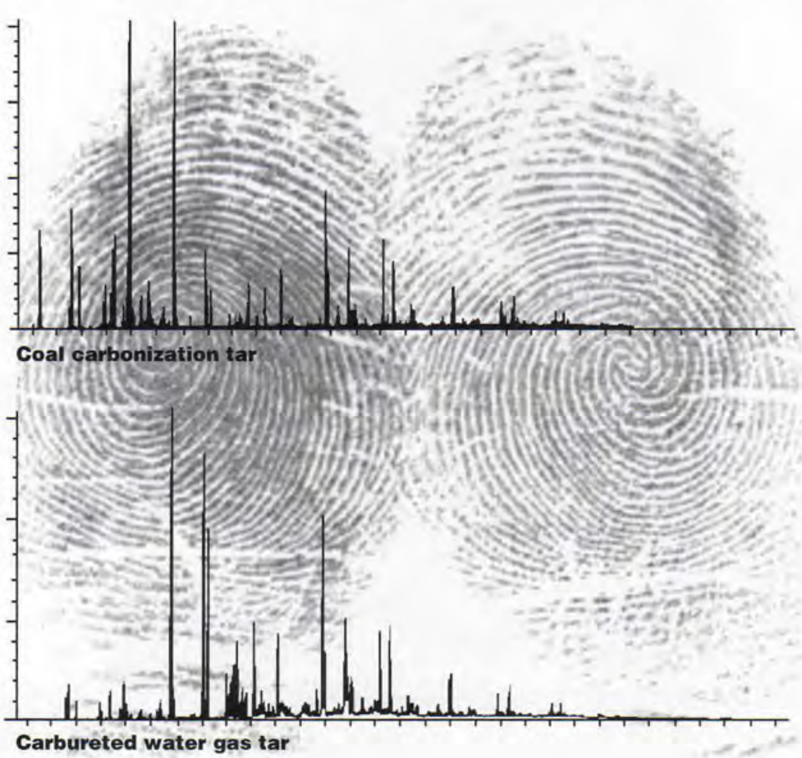
EPRI is tackling the difficult challenge of identifying and differentiating between typical MGP contaminant sources, including coal tar, carbureted water gas tar, oil gas lampblack, pitch, and refined petroleum products. The literature points out distinguishing physical and chemical characteristics for many of these materials. Until now, however, only limited use has been made of sophisticated source identification techniques to compare the chemistry of MGP process residuals and other potential sources of contamination at MGP sites.

The EPRI analyses have already identified subtle distinctions between contaminants, often discerned only in the residues' minor constituents. For example, the chromatographic fingerprints of coal carbonization tar and carbureted water gas tar are very similar, but the former typically contains significant amounts of organic acids while the latter contains only traces of those compounds. An acid fractionation process can be used to distinguish between them.

The chemical differences between refined petroleum products and MGP tarry residues are much more striking than those between various MGP process tars, and these differences are often clearly visible when standard gas chromatograms are examined. For the EPRI research, samples are being analyzed by gas chromatography with mass spectrometric detection and/or gas chromatography with flame ionization detection. Several pattern recognition techniques are being used to interpret the analytical results.

The objective of this work is to determine whether a distinct set of patterns or clusters of samples can be found, using target compounds—specific polycyclic aromatic hydrocarbons, for example—as variables. The source of the samples in each cluster will be carefully reviewed in order to develop correlations between the chemical patterns, as determined by chromatography, and the sources of the contamination. In addition, the results will be used to examine ways of quantifying the relative contributions of two or more sources of contamination in a sample containing contaminants derived from various sources. A database, a computer software program, and an accompanying technical guide will be developed on the basis of the chemical results and data analysis.

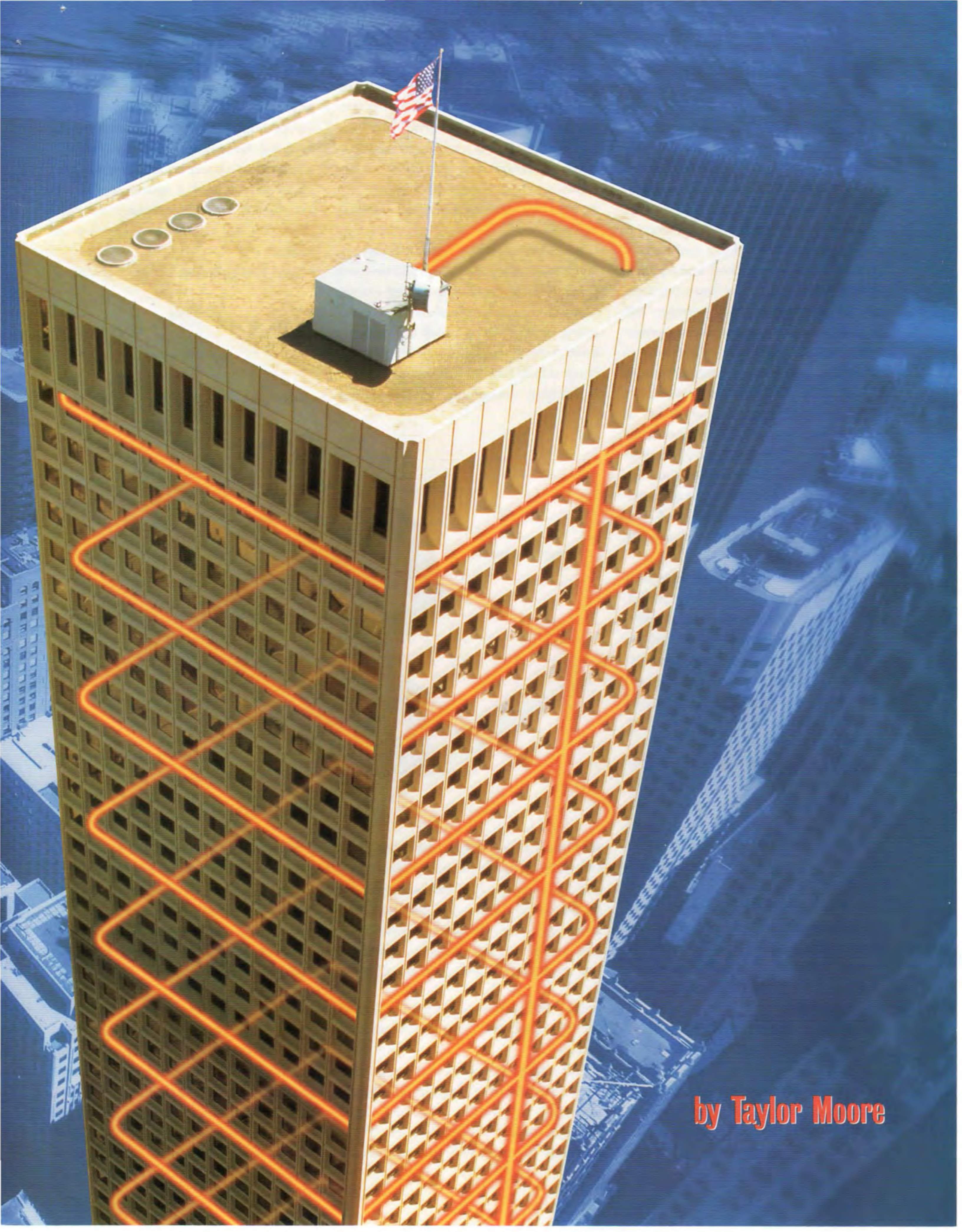
■ *For more information, contact Ishwar Murarka, (415) 855-2150.*



Gas chromatographic fingerprints for coal carbonization tar and carbureted water gas tar are very similar, but these residues can be clearly distinguished through an additional acid fractionation analysis.

High Market Potential for Fuel Cells

THE STORY IN BRIEF With the advantages of modularity, high reliability, top efficiency, and pollution-free operation, fuel cells have long been seen as a power option that is custom-made for the twenty-first century. Now, as advanced, lower-cost fuel cells approach commercialization, planners are predicting substantial market opportunities in applications such as distributed utility power, on-site customer generation, grid-independent power, and electric vehicles. In addition to supporting technology development for such units, EPRI is providing technical assessments and business intelligence that can help members develop fuel cell investment strategies. A few utilities are already pursuing business arrangements with fuel cell manufacturers to distribute the technology in competitive customer markets.


by Taylor Moore

Fuel cell generators are a technological wonder, producing electricity, heat, and water electrochemically, with no moving parts, noise, or pollutant emissions. Used for decades in spacecraft and other specialized, high-value applications, fuel cells are on a trajectory to break through economic and commercial barriers to a multitude of distributed power markets and applications in the next few years, just when competition between electricity providers will be rising to a boil. Although early-generation fuel cell technologies continue to struggle to gain market toeholds because of high costs, advanced fuel cells under development—in unit sizes of 20 kW to 1 MW or larger—show strong promise for substantially lower costs and high operating efficiencies. Such features are expected to make these advanced technologies directly competitive with retail electricity rates for commercial customers in many utility service areas.

Compact and highly modular, fuel cells can be installed almost anywhere, including in most buildings and perhaps someday in practical automobiles. At sizes of 20 kW to about 2 MW, they offer strategic efficiency and performance advantages over conventional generation technologies like industrial gas turbines, combined cycles, and diesel generators.

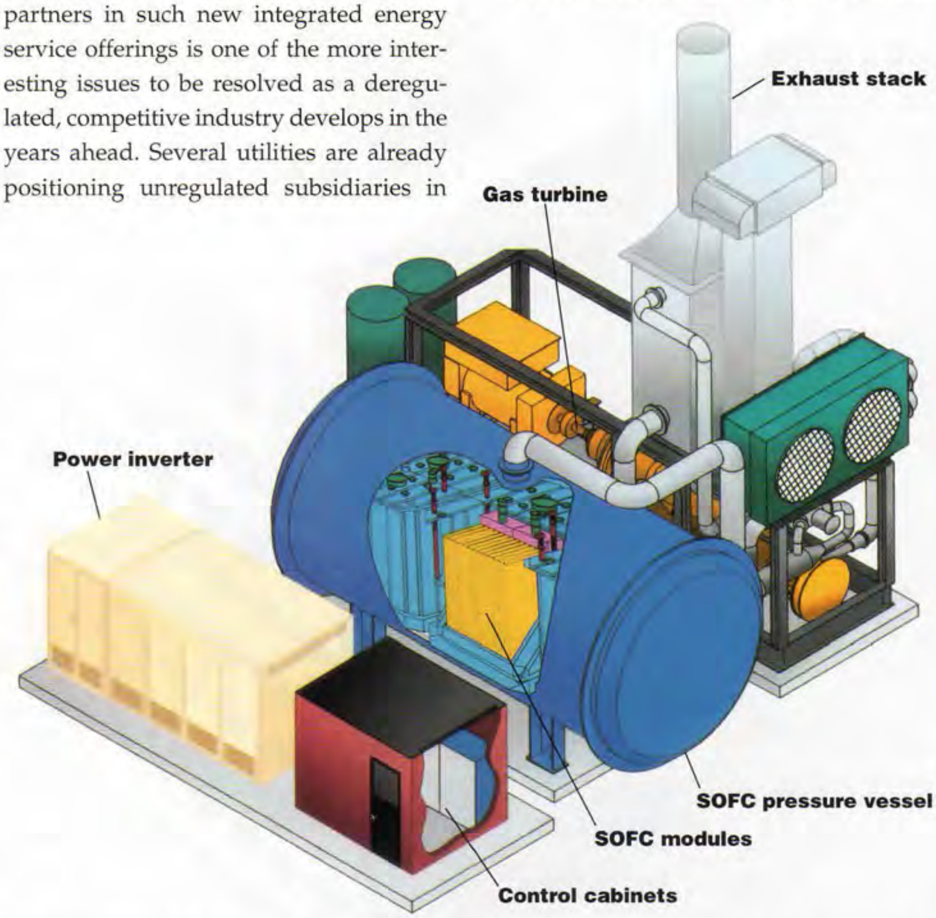
One advanced fuel cell technology—solid oxide—is expected to provide an almost ideal match with small gas turbines, resulting in an innovative power cycle with the potential for unprecedented electrical efficiency, approaching and possibly exceeding 70%. Such a high-efficiency configuration would have the lowest carbon dioxide emissions of any fossil power generation system ever considered and has been an ultimate dream of EPRI specialists in advanced generation technologies for the past 20 years.

EPRI expects that by the turn of the century, manufacturers will be offering fuel cells to commercial and industrial customers at competitive prices, either through distribution networks developed in joint ventures with fuel cell suppliers or as suppliers to energy service companies that provide their customers with a total energy package. Such a package would feature premium service in terms of power quality and reliability. Another likely market-entry product is a packaged combination of advanced fuel cells with heating, ventilating, and air conditioning (HVAC) systems for commercial-sector building markets.

Whether historically regulated, monopoly-market utility companies will be direct partners in such new integrated energy service offerings is one of the more interesting issues to be resolved as a deregulated, competitive industry develops in the years ahead. Several utilities are already positioning unregulated subsidiaries in new business relationships to ensure a role for their companies as fuel cell markets emerge.

"It's satisfying to see something close to a commercial fuel cell product on the market now," says Rocky Goldstein, EPRI's manager for fuel cell technologies. "We're not quite there yet in a cost-competitive sense, but we're getting very close." Goldstein began working on fuel cells in 1961 at Pratt & Whitney, the contractor that developed the first practical fuel cells for the National Aeronautics and Space Administration (NASA), and he acknowledges the importance of the U.S. space program: "It led directly to the technology development that has brought us where we are today."

Says Daniel Rastler, manager of the fuel cell and distributed generation program in EPRI's New Generation Business Area, "Fuel cell technology has been advancing rapidly in performance improvement and cost reduction over the past few years. In fact, fuel cell systems designed for retail customer markets, as opposed to bulk power markets, present utilities with a sig-

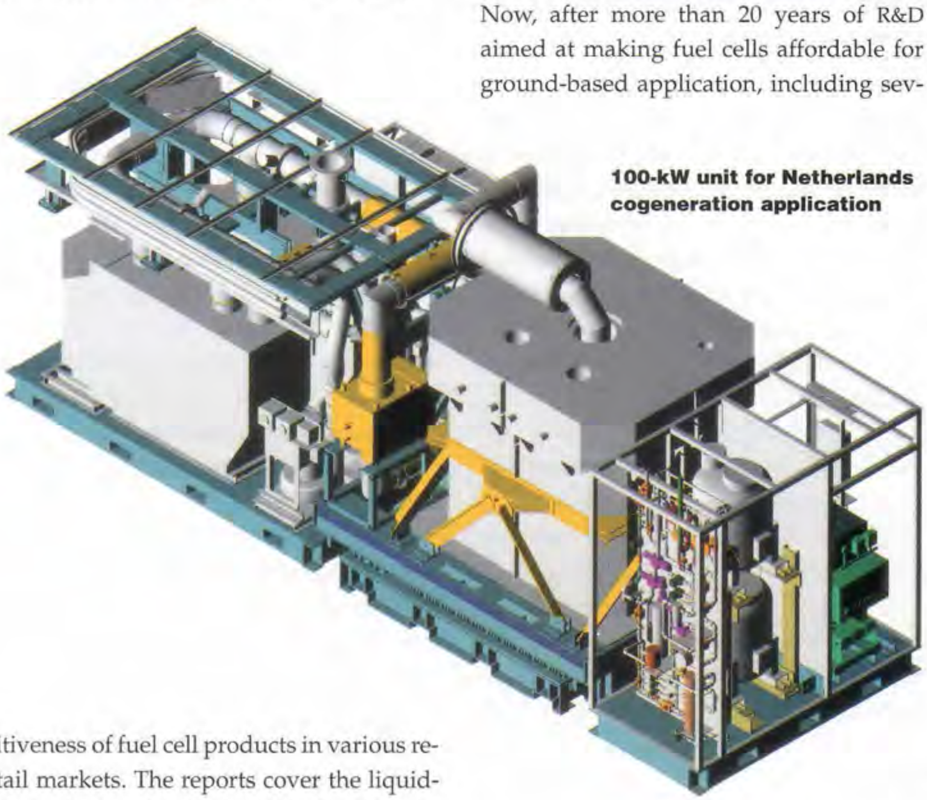


WESTINGHOUSE AIMS AT MEGAWATT SCALE Westinghouse Electric has developed tubular SOFC technology that promises to be cost-competitive for megawatt-scale distributed power applications. Packaged units that integrate pressurized SOFC modules with a gas turbine—SOFC-GTs—could achieve efficiencies of over 70% in larger unit sizes. Westinghouse has tested SOFC modules with utilities in Japan and with Southern California Edison. An experimental 100-kW SOFC is slated for installation in the Netherlands later this year in a cogeneration application.

PHOTO ON PREVIOUS PAGES BY WEINBERG & CLARK nificant strategic opportunity to preserve or grow market share—if they can quickly gain an understanding of the technology's potential and formulate competitive business strategies that maximize the growth opportunities."

To provide critical support for such strategies, EPRI has in the past year produced several assessments of emerging fuel cell technologies. These assessments present a wealth of inside information on vendor capabilities, technology performance status, commercialization issues, and the competitiveness of fuel cell products in various retail markets. The reports cover the liquid-electrolyte technologies already entering utility and on-site customer service—phosphoric acid fuel cells (PAFCs) and molten carbonate fuel cells (MCFCs)—and next-generation technologies, such as solid oxide fuel cells (SOFCs) and proton exchange membrane (PEM) cells. Recent progress with the next-generation technologies has experts more confident than ever about the commercial prospects for fuel cells in distributed generation applications.

Building on NASA's pioneering development of fuel cell technology, a broad coalition of government and industry R&D programs has supported most of the work on terrestrial applications. These groups include the U.S. Departments of Defense and Energy, the Gas Research Institute, the Institute of Gas Technology, and EPRI. As a direct result of this R&D support, 10 major technology development companies in the United States, along with about a dozen major companies in Japan and Europe, have active programs aimed at commercializing fuel cells for various markets and applications. At least another half dozen small startup companies in this country have initiated fuel cell development efforts.



100-kW unit for Netherlands cogeneration application

Finding fits in market niches

Now, after more than 20 years of R&D aimed at making fuel cells affordable for ground-based application, including several field demonstrations and the monitoring of dozens of operating units in the field, "we are emerging into a new era of strategic business priorities for electric utilities and are taking a new look at where and how fuel cells fit," says Rastler.

"As wholesale and retail electricity markets become more competitive with the approach of deregulation, it's becoming pretty clear that most fuel cells, except for the very high efficiency systems, are not going to be competitive in a wholesale power market anytime soon," Rastler continues. "But fuel cells will find a retail market as a source of grid-independent on-site power and as grid-connected premium-power generators that are part of total energy service offerings. Some companies, including Equitable Resources and Carrier, are already offering such services to commercial customers with critical loads, like hospitals, or with special power quality requirements, like data-processing centers and some high-technology manufacturers. Other companies—for example, Enron—have piloted energy service offerings that include fuel cells.

"Those kinds of services can be profitable opportunities to install fuel cells because the customers are willing to pay more for energy services that go beyond the traditional kilowatthours and capacity values. Studies we've done suggest the market for such customers to be substantial, and that's where we see the higher-cost fuel cell systems like phosphoric acid and molten carbonate heading, as the developers of these technologies continue to work to drive down installed costs."

Commercially available 200-kW PAFCs, which now cost around $3000/kW (with early sales qualifying for a $1000/kW federal subsidy), are expected to find market niches in applications under 1 MW where high-reliability service is desired and where there is a need for cogenerated low-temperature steam. The leading producer of PAFCs—International Fuel Cells—is a joint venture of Toshiba of Japan and the Hamilton Standard division of Pratt & Whitney's parent company, United Technologies Corporation. UTC has committed substantial resources to lowering installed costs for PAFCs to around $1500/kW.

MCFCs, which operate at a higher temperature and are more efficient than PAFCs, are expected to fit best in larger (1–20 MW) baseload distributed power applications, particularly in certain industrial markets where cogeneration opportunities exist. If built in low numbers, MCFCs are likely to cost around $3000/kW. If costs can be reduced to $1500/kW, which would require order commitments to support high-volume manufacturing, these systems could find significant utility markets for distributed generation in grid-support applications. In a demonstration project cosponsored by EPRI and a number of utilities, a 2-MW MCFC pilot unit in Santa Clara, California, recently completed 4000 hours

ARTWORK COURTESY WESTINGHOUSE ELECTRIC CORP.

of successful test operation.

Barring dramatic cost reductions, however, the liquid-electrolyte PAFCs and MCFCs may be cost-effective only in special applications, such as for areas with severe restrictions on emissions or siting. Third-generation technologies like SOFCs and PEM fuel cells have greater mass-market potential for retail energy service applications in sizes down to 100 kW and smaller—a scale that should enable them to fill early-market niches and thus realize manufacturing economies and market-competitive production costs sooner.

Test of Westinghouse 20-kW module at SCE

PEM fuel cells are of interest to automobile manufacturers as future mini–power plants (about 50 kW) for electric vehicles. In addition, their quick-start capability, ruggedness, and potentially low cost make them attractive for stationary distributed power applications, including remote off-grid applications. These fuel cells operate at a comparatively low temperature (70–100°C), using a moist polymer membrane electrolyte. PEM cells are targeted for use in continuous premium-power service and as small peaking generators in retail markets. Although their operating efficiency is expected to be somewhat lower than that of commercial PAFCs, experts believe PEM fuel cell generators could achieve installed costs below $1000/kW for continuous premium-power service and below $500/kW as peaking units. Meeting such cost targets would make them competitive as standby, backup power sources or as distributed peaking capacity.

EPRI considers SOFCs, which employ a ceramic, solid-state electrolyte (zirconium oxide stabilized with yttrium oxide), the only fuel cell technology with the potential to span market-competitive applications from residential loads as small as 2 kW to wholesale distributed generation units of 10–25 MW. Because SOFCs operate at a higher temperature than MCFCs, their simple system efficiency (around 50%) is theoretically not quite as good as that of MCFCs, although it is better than the efficiencies of PAFCs and PEM fuel cells. But the 850–1000°C waste heat that SOFCs produce, when used for cogeneration or for driving an integrated gas turbine, can boost overall system energy efficiency to very attractive levels. Moreover, SOFCs operate at a high enough temperature to incorporate in their design an internal fuel reformer that uses heat from the fuel cell—along with recycled steam and a catalyst—to convert natural gas directly into a hydrogen-rich fuel.

High-efficiency systems coupling advanced SOFCs with small gas turbines and having a combined rating in the range of 250 kW to 25 MW are expected to fit into grid-support or industrial on-site generation markets, and they potentially could compete head-on with wholesale power rates. Both PEM fuel cells and SOFCs could someday be suitable for small-scale residential market applications if ultimate cost goals are reached.

SOFCs: heading for commercialization

Materials durability, low-cost cell manufacturing processes, overall system cost reduction, and definition of high-value market-entry products are critical challenges in the early commercialization of SOFCs, which are less developed and therefore have a less certain cost basis than PAFC and MCFC systems.

Westinghouse Electric Corporation is the current leader in SOFC technology in terms of the number and size of test units and their cumulative hours of operation. With substantial DOE funding as well as internal funding and support from utilities and other agencies, Westinghouse's Science & Technology Center has developed a tubular SOFC design, which has recently been improved with a higher-performance, lower-cost air-electrode-supported cell. The company has built a $13 million pilot manufacturing facility capable of producing about 4 MW of SOFCs a year.

Westinghouse has conducted several demonstrations of fully integrated, experimental 25-kW systems, some at its facilities and some in cooperation with Southern California Edison and with several utilities in Japan. The SOFCs have performed well and appear to promise acceptable component life characteristics; the latest system operated for over 13,000 hours before being intentionally shut down. Last year, EPRI, SCE, and Westinghouse tested a 20-kW module and a 25-kW module at an SCE facility. One of these used the latest air-electrode-supported cell design and was operated on jet fuel and diesel fuel (requiring a separate fuel-processing unit) in addition to natural gas.

An experimental 100-kW system currently being fabricated by Westinghouse is to be installed in a cogeneration application in the Netherlands later this year under a contract with a consortium of Dutch and Danish utilities.

Although it has studied SOFC applications as small as 200 kW, Westinghouse is focusing on multimegawatt systems that combine fuel cells with a gas turbine in packaged units rated up to about 20 MW. Known as SOFC-GTs, such systems promise very high electrical efficiency—60% to possibly over 70%. They have the potential for achieving competitive cost targets ($1000–$1200/kW) at the 1–5-MW scale, assuming high-volume manufacturing of several hundred megawatts per year.

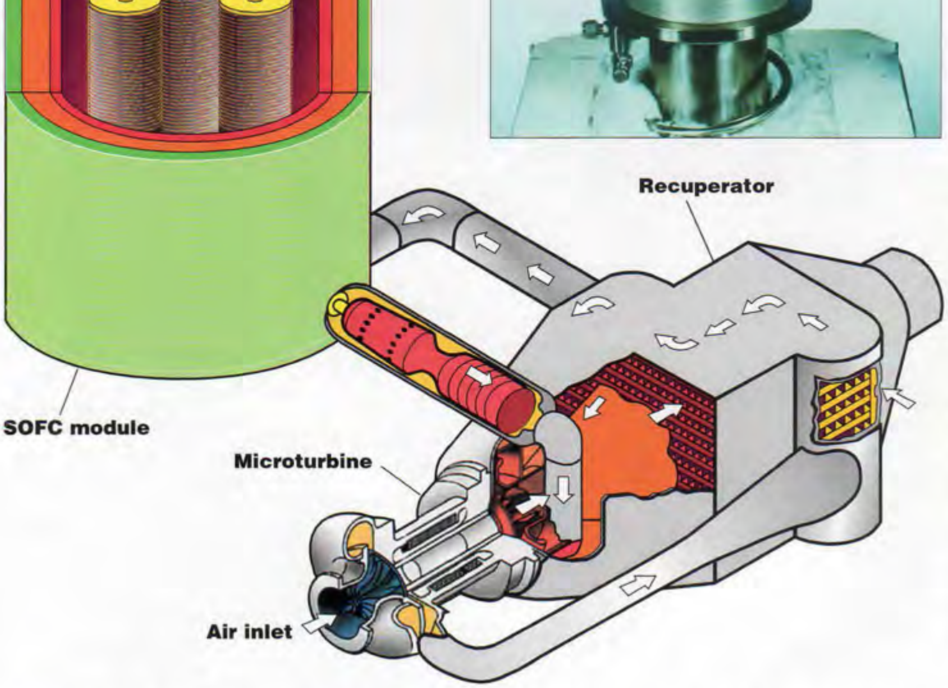
Some of the experimental SOFC stacks built by Westinghouse have been tested in enclosed vessels under pressurized conditions of up to 15 atmospheres. Pressurized operation makes it possible to integrate fuel cells with a gas turbine and—in SOFCs as in other types of fuel cells—results in improved electrochemical reactions and increased performance. Westinghouse envisions its market-entry product as a 1.3-MW SOFC-GT system in which the fuel cells operate at approximately 4 atmospheres of pressure. According to the company, this system could be available as early as 2001 and is expected to have an efficiency of at least 63%.

In a proposed extension of its DOE-funded SOFC development program, Westinghouse has plans to test a 100-kW cogeneration system and demonstrate SOFC-GT systems ranging in size from 250 kW to 2.5 MW before 1999. The company also plans to begin construction of a commercial SOFC manufacturing facility in the same time period. Westinghouse has indicated plans for an initial product line of distributed SOFC-GT systems in the range of 1–7 MW. It is discussing with several utilities the formation of a joint venture to complete the development and commercialization of its SureCell technology.

As an alternative to Westinghouse's tubular SOFC design, several other development companies are working on planar SOFC designs, which feature flat-plate cell stacks and potentially offer lower-cost manufacturing and assembly. One planar SOFC developer, Ztek Corporation, has operated a 1-kW cell stack for over 15,000 hours. By the end of this year, a 25-kW module is expected to be operating on a utility system.

A small, privately held development company in Waltham, Massachusetts, Ztek has developed proprietary planar SOFC technology with support from EPRI and the Tennessee Valley Authority. In partnership with Ztek, TVA and one of its local distributors—the Huntsville, Alabama, Utilities Board—are planning to install and begin testing the first 25-kW Ztek SOFC module in a commercial setting by late this year.

1-kW Ztek SOFC submodule



PLANAR SOFC NEARS U.S. DEMONSTRATION Ztek Corporation has developed a planar SOFC system based on pressurized 25-kW modules that can be integrated in varying numbers with gas turbines for a wide range of SOFC-GT unit sizes. In the drawing, one module is coupled with a microturbine (not yet commercially available) in a configuration that promises 60% efficiency in units as small as 100 kW. A 25-kW module is to be installed on the Huntsville, Alabama, utility system later this year.

Anda Ray, manager of energy generation technologies in TVA's Technology Advancements organization, says TVA expects SOFC technology, particularly in combination with a gas turbine, to be one of the most cost-effective options for distributed generation applications over the next several years. "TVA must offer more value-based choices to meet the changing needs of our existing customers and new customers, and we are particularly optimistic about Ztek's planar SOFC leading-edge design and its maintainability," says Ray. "TVA is excited about the new opportunities and challenges facing us, and fuel cells are a technology that we will use to help us successfully meet those challenges."

According to Michael Hsu, Ztek's president, and Daniel Nathanson, vice president for fuel cell systems, the company's market-entry strategy is focused on two distinct product lines. The first is a high-efficiency 250-kW packaged system that would integrate a small (60–100 kW) gas turbine with seven 25-kW SOFC modules. The second is a high-efficiency package combining an SOFC module with an HVAC system in the capacity range of 15–100 kW.

Ztek's 25-kW module is designed as a building block. By combining these modules and matching them with various sizes of gas turbines, a wide range of unit sizes is possible. The module being built for installation in Alabama is designed for pressurized operation, although it will be operated at atmospheric pressure. Ztek is hoping to complete and begin testing a 250-kW SOFC-GT unit, with the fuel cell modules pressurized to 5 atmospheres, in 1998. The company anticipates commercial availability of SOFC-GT units by 2000, with market-competitive pricing within a year from then, says Nathanson.

Other companies that are pursuing the development of planar SOFC technology include SOFCo (a partnership between Elkem's Ceramatec unit and McDermott International's Babcock & Wilcox subsidiary), the venture company Technology Management Incorporated, and the aerospace manufacturer AlliedSignal Corporation. Both SOFCo and Technology Management are focused on market-entry SOFCs of 25 kW to 400 kW combined with HVAC systems in units for small commercial retail markets and perhaps multifamily housing markets.

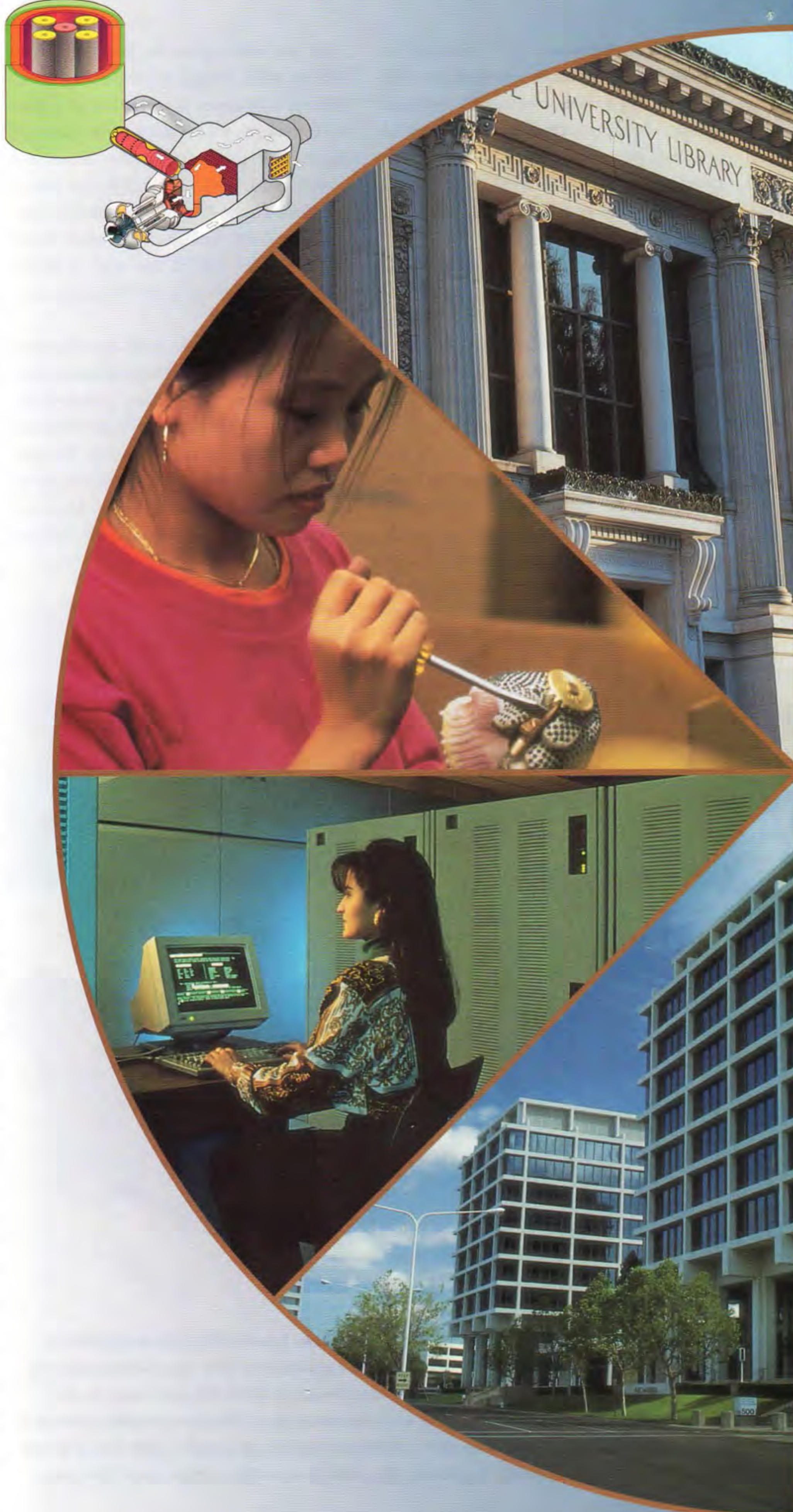
AlliedSignal maintains a modest SOFC stack development effort in a cooperative venture that includes Argonne National Laboratory. Also, because it is pursuing development of microturbines, the company has a strategic interest in the prospects for SOFC-GT units. AlliedSignal and others, including the startup firms Capstone Turbine Corporation and Elliott Energy Systems, are developing microturbines that potentially could be integrated with an SOFC to form a high-efficiency (around 60%) power plant small enough to fit in a broom closet. Microturbines promise to be low in cost as a result of manufacturing economies realized for automobile turbochargers.

Elevating efficiency to a higher plane

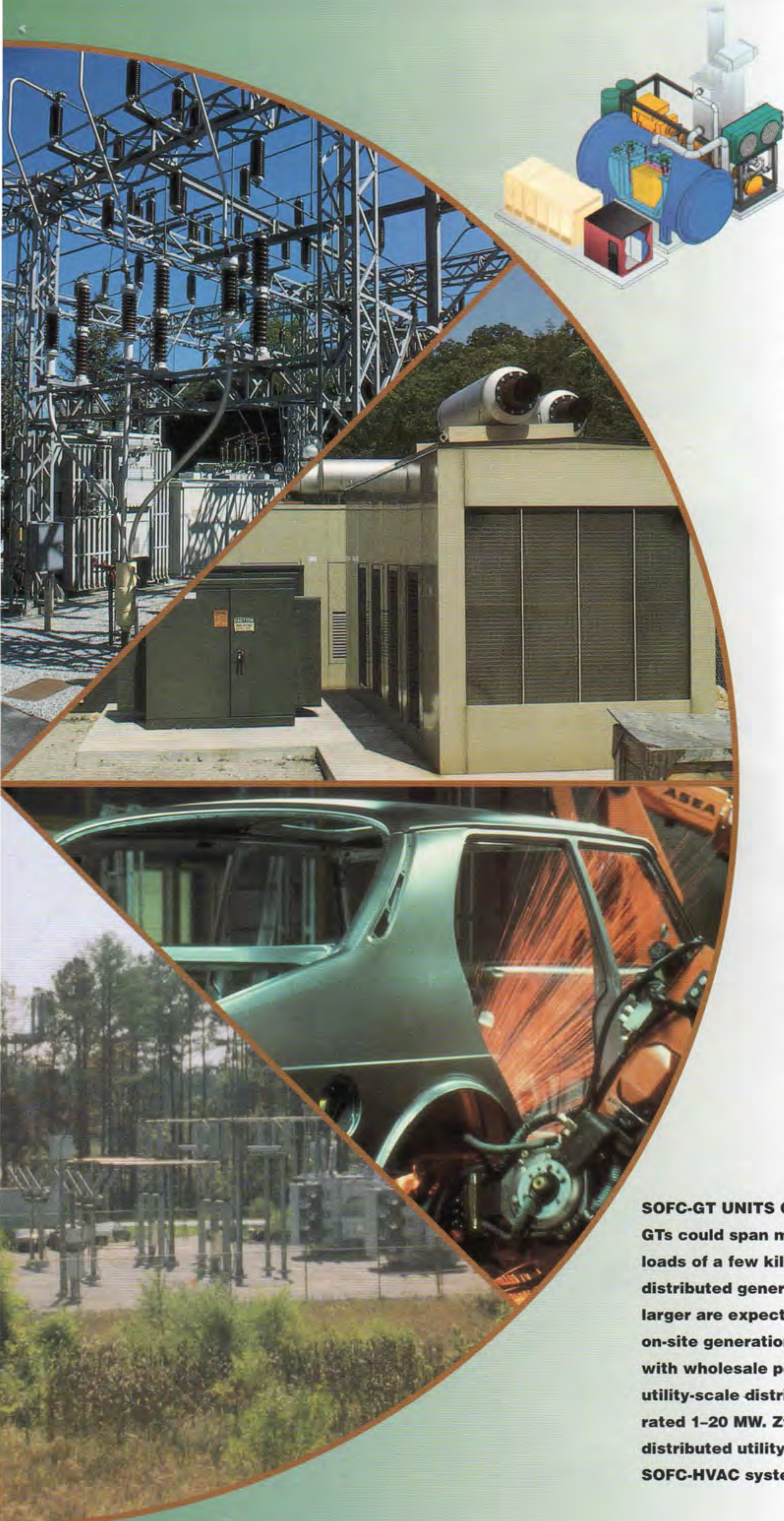
The integration of SOFC modules with microturbines or larger gas turbines has considerable technical and commercial promise. It could lead to a flood of distributed generation products designed for specific market segments over the next 5 to 10 years—products spanning a wide range of applications.

Unprecedented efficiencies are possible when gas turbines and SOFCs work together. The turbine's compressor section can be used to pressurize the fuel cell stack, and the hot exhaust from the stack, which still contains about half of the fuel's energy (as heat and fuel), can be combusted and expanded to drive the turbine, extracting another 20–30% of heating value. Energy is recovered from the turbine exhaust in a recuperator that heats the pressurized inlet air for the fuel cell stack and the compressed inlet air for the turbine. Additional remaining energy may be used for cogenerated heat applications or steam production.

"SOFC-GT systems have performance and size characteristics that make them stand out from all the other advanced power cycles EPRI has evaluated," says



PHOTOS BOTTOM LEFT TO TOP: BRETT H. FROOMER/IMAGE BANK; GABRIEL COVIAN/IMAGE BANK; T. ANDERSON/IMAGE BANK; WEINBERG & CLARK/IMAGE BANK



Daniel Rastler. "They truly represent a high-efficiency breakthrough technology for distributed power markets." Adds Arthur Cohn, an EPRI technical manager who has long studied advanced cycles, "It's been recognized for about 20 years that SOFC-GT configurations have the potential to beat the efficiency of any other thermal power cycle we've ever looked at or heard of. Until recently, however, solid oxide fuel cells were confined to laboratory development, and their costs were uncertain. Now it looks as though SOFCs will be on the market in a few years and will be economical for SOFC-GT units."

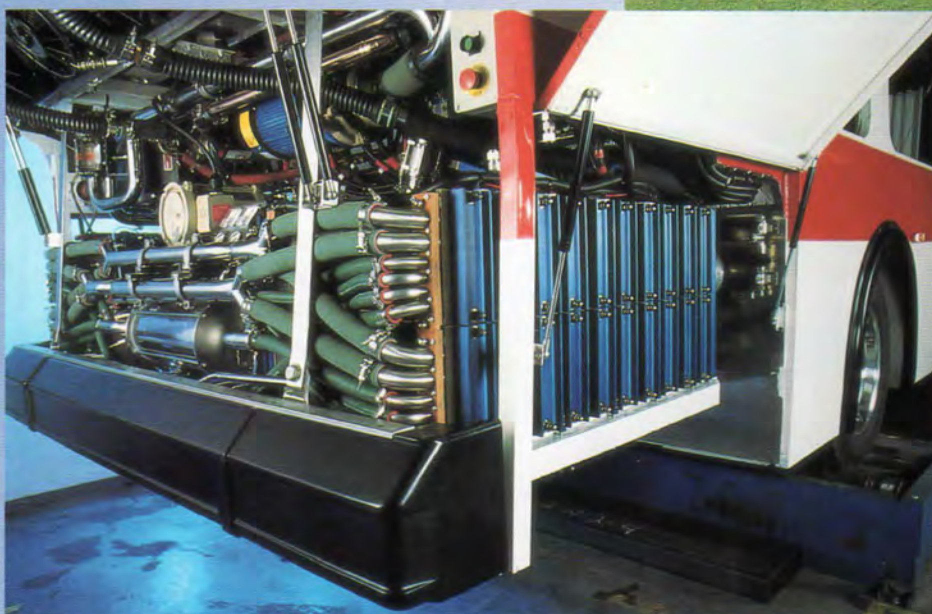
As Cohn notes, there is thermodynamic and economic synergy in the combination of the high-temperature SOFC with a mature, off-the-shelf gas turbine. Using a low-cost (\$200–\$400/kW) turbine as the balance of plant (BOP) for a higher-cost SOFC, which serves as a generator and partially as a combustor for the turbine, results in a lower overall capital cost and higher operating efficiencies than offered by an SOFC alone or other fuel cell systems of comparable size.

In an SOFC-GT power plant, the fuel cell would be operated continuously at maximum power rating—sacrificing a few percentage points of efficiency, since fuel cells run most efficiently at low power output. "Even though it may be slightly less efficient to operate the fuel cell in this way, the fuel that is not converted to electricity in the cell is still available for combustion to produce hot gas that drives the turbine," says Cohn. "Thus you accept a small loss in potential efficiency for a large gain in power output for a given number of fuel cells. This translates into tremendous savings in cost per kilowatt of the combined

SOFC-GT UNITS OFFER VARIETY OF APPLICATIONS SOFC-GTs could span market applications from small residential loads of a few kilowatts to units of 10–25 MW for wholesale distributed generation. High-efficiency systems of 250 kW or larger are expected to compete in grid-support and industrial on-site generation markets and could potentially compete with wholesale power rates. Westinghouse is targeting utility-scale distributed power applications with systems rated 1–20 MW. Ztek is focusing on 250–400-kW SOFC-GTs for distributed utility or on-site customer generation and an SOFC-HVAC system of 15–100 kW for commercial buildings.

PHOTOS BOTTOM RIGHT TO TOP: CHATTANOOGA ELECTRIC POWER BOARD; JAY FREIS/IMAGE BANK; WHITE RIVER VALLEY ELECTRIC COOPERATIVE, INC.; DAVID MORIN/EPRI

PEM CELLS TARGET STATIONARY AND MOBILE MARKETS PEM fuel cells under development for vehicle applications are also targeted for use in premium-power service and as small peaking generators in retail markets. The leading PEM system developer—Ballard Power Systems—is building prototype commercial buses powered by 275-hp PEM generators fueled with hydrogen. A joint venture with GPU International—Ballard Generation Systems—is commercializing 250-kW stationary generators, with a prototype now under evaluation in Canada. Ballard Generation expects to offer precommercial systems in 1999.



PHOTOS COURTESY BALLARD GENERATION SYSTEMS

275-hp PEM fuel cell engine

One of the stationary prototype's PEM cell stacks

250-kW stationary PEM generator: under construction and fully assembled capacity," he explains, noting that "once you're into a regime of such high efficiency with an SOFC-GT, you want to optimize the cost per kilowatt."

EPRI conservatively estimates the U.S. market for SOFC-GT systems to be around 500–600 MW a year over the next 10 years. Overseas markets could easily be twice that size. Likely early U.S. markets are industrial parks, which can incorporate fuel cells as part of an integrated energy service solution. Secondary markets could be in grid-support applications that provide environmental siting solutions in emissions-constrained urban areas.

Other potential early-market customers for SOFC-GTs are rural electric generating and transmission utilities facing load growth on constrained transmission and distribution systems. Public power entities could use SOFC-GTs in a competitive market to better manage distribution systems and retain key commercial and industrial customers. Several rural electric cooperatives have already been getting familiar with fuel cells through short-term demonstrations with a mobile 200-kW commercial PAFC unit.

Given their lower capital requirements and a larger pool of potential early adopters, small SOFC-GT systems of around 500 kW may be simpler to bring to the commercial market than megawatt-scale systems, says EPRI's Rastler. An EPRI commercial-sector market assessment for SOFCs last year identified approximately 60,000 U.S. customer sites—representing an aggregate load of 24 GW—where on-site generation could be competitive with existing utility rates. The most likely early adopters include hospitals, health care facilities, hotels, and office buildings that require premium-power service.

Even more powerful and efficient SOFCs are anticipated within just a few years as a result of materials science work sponsored by EPRI Strategic R&D. The recent achievement of a record single-cell power density has added to optimism among experts that higher-performance advanced fuel cells can be economically manufactured for commercial application. Working with small cells in the laboratory, researchers under the direction of Anil Virkar, a professor of materials science at the University of Utah, and Steve Visco at Lawrence Berkeley National Laboratory have developed cathode, anode, and electrolyte layers that have resulted in cell power densities more than five times the levels typical of full-size SOFC multicell stacks. "There are good prospects over the next two to three years for getting these advances incorporated into a commercially viable manufacturing process," says EPRI's Rocky Goldstein.

Applications for PEM cells

Proton exchange membrane fuel cells, which are approaching the pilot system and field demonstration phase, have excellent transient response and quick-start capabilities that make them of interest for on-site premium-power service and as distributed peak-power generators. Because of their lower system operating temperature (70–100°C), they face much more tractable materials challenges, such as those related to corrosion and cycle life, than other fuel cell technologies.

Of the approximately $60 million a year going into PEM fuel cell development in North America, about half is focused on light-duty transportation vehicles, including electric vehicles; the other half is about evenly split between heavy-duty vehicles (buses), stationary power applications, and military applications. Transportation applications require high power density and have moderate stack life requirements. Because of the fuel cell catalyst's sensitivity to carbon monoxide, one of the critical technical issues for most applications is the need for a low-cost fuel processor to produce nearly pure hydrogen.

At least nine companies in North America have active PEM fuel cell programs in various stages of development. The current technical leader is Ballard Power Systems, based near Vancouver, British Columbia. In a development program that began in 1993 with substantial funding from the German automaker Daimler-Benz, Ballard has produced PEM fuel cell stacks of sufficient power density—and sufficiently low weight and volume—for practical use in automobiles. Dramatic reductions in cost remain a key hurdle, however. Under contracts with General Motors, Honda, Nissan, Volkswagen, and Volvo, Ballard has delivered PEM fuel cell stacks for experimental evaluation. In April, Ballard and Daimler-Benz announced plans to combine forces and jointly invest over $450 million in new business ventures to develop and commercialize next-generation automobile engines using Ballard's PEM fuel cells.

Two Ballard PEM power units (100 kW and 205 kW) are operating in commercial-scale zero-emission transit buses fueled by hydrogen. Six prototype transit buses powered by PEM generators are currently being built: three for delivery to the Chicago Transit Authority in June and three for delivery to B.C. Transit in September. All six will undergo two years of trial service.

David Dunnison, marketing manager at Ballard Generation Systems (a business venture that Ballard Power recently formed with a major U.S. utility to develop stationary PEM power systems), and Paul Howard, Ballard Power's transportation systems vice president, see hydrogen-fueled transit buses as a relatively small but important early niche market for PEM cells, since buses can be centrally refueled, don't require fuel processing, and don't have the weight constraints facing light-duty vehicle applications. Moreover, advances in units for buses could be readily applied in 250-kW stationary generators for service in distributed premium-power applications or as replacements for diesel generators. EPRI's Rastler says combination utilities in particular could find significant new revenue opportunities—from both gas and electricity sales—in partnerships with public transit agencies and industrial producers of hydrogen for fueling these zero-emission fuel cell buses. "We're now working to catalyze such partnerships," he adds.

Stationary PEM systems for distributed power applications will require a fuel processor to convert pipeline natural gas into hydrogen. Ballard has developed a proprietary system based on steam reforming that is smaller and is expected to cost less than other steam reformers. A 30-kW hydrogen-fueled PEM fuel cell has been installed at an industrial site.

Dunnison says that Ballard expects to begin operating a prototype 250-kW PEM stationary generator at its facilities by the middle of this year. Although recent media attention has focused on transportation applications, particularly advanced electric vehicles, Ballard expects the first big market for PEM systems to be stationary distributed power applications, not the 100-times-larger automobile market. "PEM systems will be competitive in stationary applications before they will be for automobiles," says Dunnison. "We expect the stationary markets to provide us with an experience base that we can use to drive the technology costs down to compete in future transportation markets."

With feasibility and acceptable power density for PEM fuel cells now well established, the focus is on overall technology development and integration and on both stack and BOP cost reduction. For grid-connected distributed power applications, the BOP must include a high-efficiency, affordable inverter to turn the fuel cell's direct current output into alternating current. Stationary power markets are expected to materialize for PEM systems if installed costs can be brought down to \$1500/kW or lower. Comparable targets for automobile applications are lower still by a factor of 15–30.

U.S. automakers and federal agencies are evaluating PEM fuel cells and other advanced high-efficiency technologies under the collaborative Partnership for a New Generation of Vehicles program. Ford announced in April that as part of its participation, it will develop a prototype fuel cell vehicle with onboard hydrogen storage.

But it is recent progress in developing an economically promising fuel processor technology for use with PEM fuel cells in vehicles that is increasing optimism about the commercial prospects of both mobile and stationary applications. With funding from DOE's Office of Transportation Technologies and the state of Illinois plus internal funding, Arthur D. Little (ADL) developed a compact, lightweight multifuel reformer that can convert gasoline and such alternative vehicle fuels as methanol, ethanol, natural gas, propane, and even biogas into hydrogen-rich gas for PEM fuel cells.

The ADL process begins by vaporizing the fuel and partially oxidizing it with air to produce hydrogen and carbon monoxide. Using steam and a catalyst, a shift reactor then converts most of the carbon monoxide into carbon dioxide and produces more hydrogen. Finally, air is injected over a catalyst and reacts with the remaining carbon monoxide to convert it to carbon dioxide, leaving hydrogen-rich gases.

After conducting an independent evaluation of ADL's fuel processor technology, Chrysler announced earlier this year that it had contracted with the components division of General Motors to develop a 40-hp, 30-kW prototype gasoline-powered fuel cell vehicle engine that would integrate the ADL unit with Ballard's PEM stacks. GM's Delphi Engine & Engine Management Systems unit has placed a \$3 million order for Ballard PEM stacks under the Chrysler contract.

Brian Barnett, an ADL vice president, says that on the basis of its independent manufacturing-cost study of the fuel processor system, Chrysler concluded that fuel-cell-powered vehicles could reach the commercial market 10 years sooner than previously thought. "The cost targets for transportation applications are so demanding that if the technology can work there," Barnett notes, "then there are serious prospects for using the reformer to take a lot of the cost out of stationary PEM systems."

Other developers of PEM fuel cells include Mechanical Technology Incorporated, which is advancing its technology through R&D contracts with Ford. The company is committed to delivering a 50-kW PEM stack to Ford sometime this year. Meanwhile, H-Power in Belleville, New Jersey, is among several PEM fuel cell developers targeting the battery replacement and dispersed generator markets.

Strategic opportunities for utilities

Many electric utilities are familiar with fuel cells, and several are already establishing business relationships aimed at developing and distributing the technology in competitive customer markets.

The above-mentioned Ballard Generation Systems, for example, is a joint venture between Ballard Power Systems and GPU International—an unregulated subsidiary of the utility holding company GPU. In 1996, GPUI announced a commitment to invest more than \$23 million in the new company, which will develop, manufacture, and market stationary fuel cell power systems using Ballard's PEM technology. The venture will initially manufacture the 250-kW unit Ballard has been developing. GPUI will install and test the performance of two prototype units.

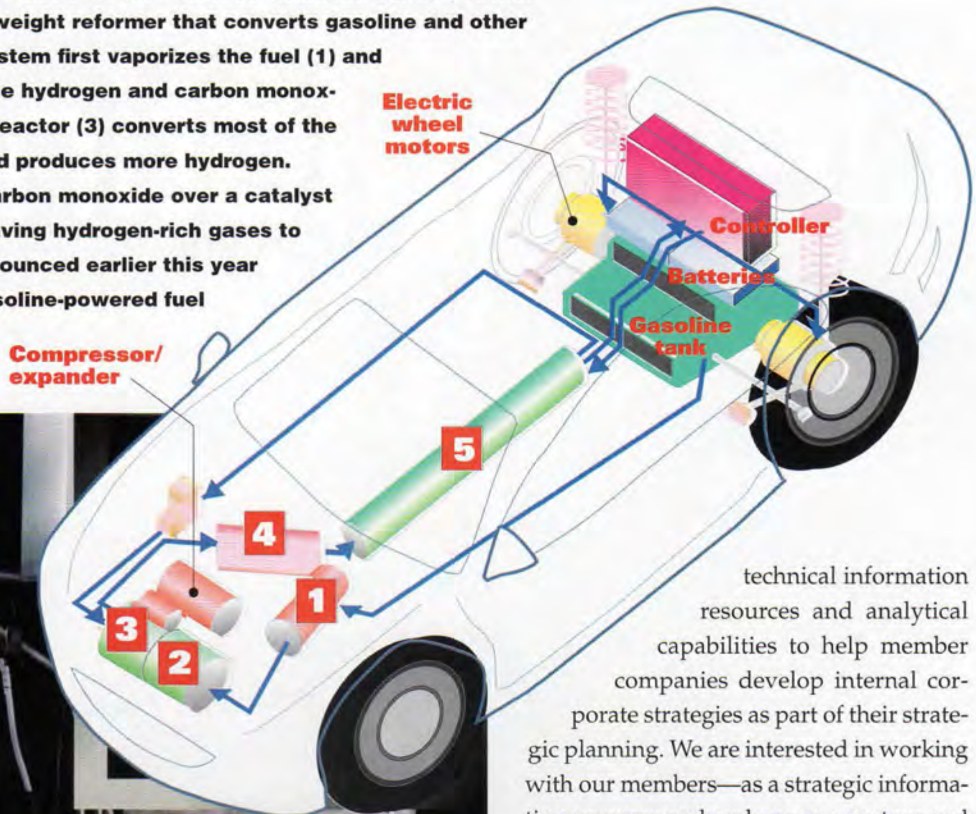
Jim Torpey, director of technology ventures at GPUI, says Ballard Generation Systems hopes to begin selling precommercial units in 1999 and to have fully commercial units on the market around 2000. "A lot of engineering and design work is going into the alpha unit now being built. We're also working on market preconditioning and making sure we have the right product for the early markets we identify." He adds that Ballard Generation will establish a global distribution network for the units, a network that could include other utilities as well as other companies.

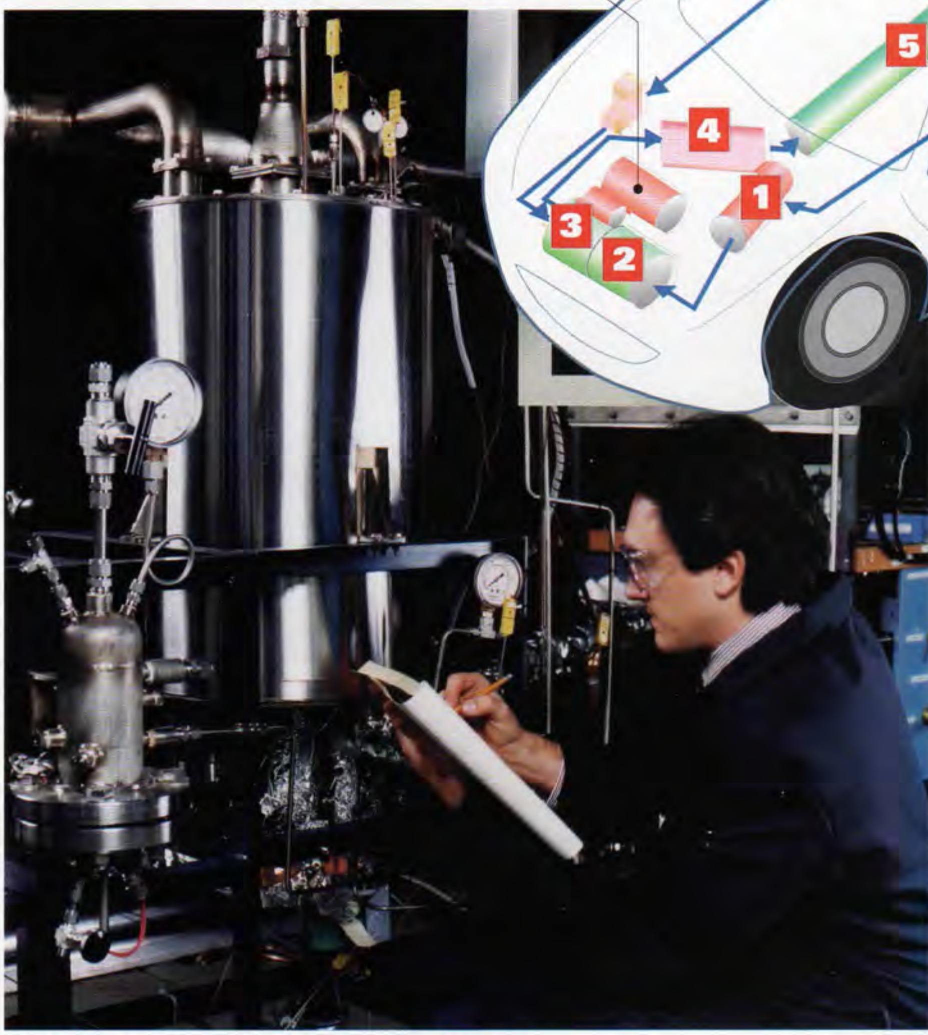
Bruce Levy, GPUI president and CEO, says, "With the deregulation of power markets around the world, the number of customers who seek high-grade on-site power is going to grow. This venture positions us to effectively meet a market need that we see growing as the twenty-first century approaches."

The Indiana-Ohio utility holding company Cinergy Corporation is also becoming familiar with Ballard Power's PEM technology. The company's unregulated subsidiary, Cinergy Technology, has licensed a 3-kW Ballard PEM generator for testing and evaluation under a cooperative R&D agreement with the U.S. Naval Surface Warfare Center's Crane Division in Indiana, where batteries and electrochemical devices for military application are tested. H-Power, meanwhile, recently announced plans with Duquesne Enterprises, the unregulated subsidiary of the Pennsylvania utility DQE, to produce a residential-scale PEM fuel cell system.

As EPRI's state-of-the-art assessments of fuel cell technologies point out, there are large barriers to the market introduction of some high-cost fuel cell technologies in the electricity industry's evolving competitive

FUEL REFORMER COULD SPUR MOBILE PEM SYSTEMS **With government support, Arthur D. Little has developed a compact, lightweight reformer that converts gasoline and other fuels into hydrogen-rich gas. The ADL system first vaporizes the fuel (1) and partially oxidizes it with air (2) to produce hydrogen and carbon monoxide. Using steam and a catalyst, a shift reactor (3) converts most of the carbon monoxide into carbon dioxide and produces more hydrogen. Injected air reacts with the remaining carbon monoxide over a catalyst (4) to form carbon dioxide and water, leaving hydrogen-rich gases to power a PEM cell stack (5). Chrysler announced earlier this year that it will develop a 40-hp prototype gasoline-powered fuel cell vehicle engine that integrates this reformer with a PEM cell stack.**





Laboratory prototype of ADL's multifuel reformer

ARTWORK COURTESY ARTHUR D. LITTLE AND CHRYSLER

environment. Certain technologies and products, however, are likely to be successfully commercialized. Emerging competitive retail electricity markets will provide greater opportunities for new players to use new technologies to offer energy services to industrial, commercial, and retail customers. Various types of companies—energy service companies, power marketers, mini–generating companies, and other third parties—will seek to use near-commercial and technically proven technologies as part of integrated energy service offerings.

"Fuel cells offer a combination of performance and flexibility that makes them ideal as distributed resources," says EPRI's Rastler. "Utilities have several options for pursuing business strategies involving fuel cell technologies. EPRI can provide unique technical information resources and analytical capabilities to help member companies develop internal corporate strategies as part of their strategic planning. We are interested in working with our members—as a strategic information resource and perhaps as a partner and costakeholder—to develop the new business opportunities we see with fuel cell technologies." ■

Further reading

Field Evaluation of Westinghouse Tubular Solid Oxide Fuel Cell Technology. Final report for WO3803, prepared by EPRI, Southern California Edison Company, and Westinghouse Electric Corporation. December 1996. EPRI TR-107125.

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Technical Assessment of Breakthrough Technology for High-Efficiency Distributed Power Systems. Interim report for WO4297-1. November 1996. EPRI TR-107075.

Advanced Planar Solid Oxide Fuel Cell Development, Phase 2: 25-kW Planar SOFC System Design. Final report for WO8509-1, prepared by Ztek Corporation. October 1996. EPRI TR-107116.

Commercial-Sector Solid Oxide Fuel Cell Business Assessment. Interim report for WO8502-1, prepared by Resource Dynamics Corporation. August 1996. EPRI TR-106645.

State of the Art of Fuel Cell Technologies for Distributed Power. Final report for WO4297-1. July 1996. EPRI TR-106620.

Residential Fuel Cells: Technology Readiness Assessment. Final report for WO3934. April 1996. EPRI TR-105832.

Solid Oxide Fuel Cells. 1996. EPRI brochure BR-106591.

"Advances in Solid Oxide Fuel Cells." *EPRI Journal*, Vol. 21, No. 5 (September/October 1996), pp. 42–45.

Background information for this article was provided by Arthur Cohn, Rocky Goldstein, and Daniel Rastler, New Generation Business Area.

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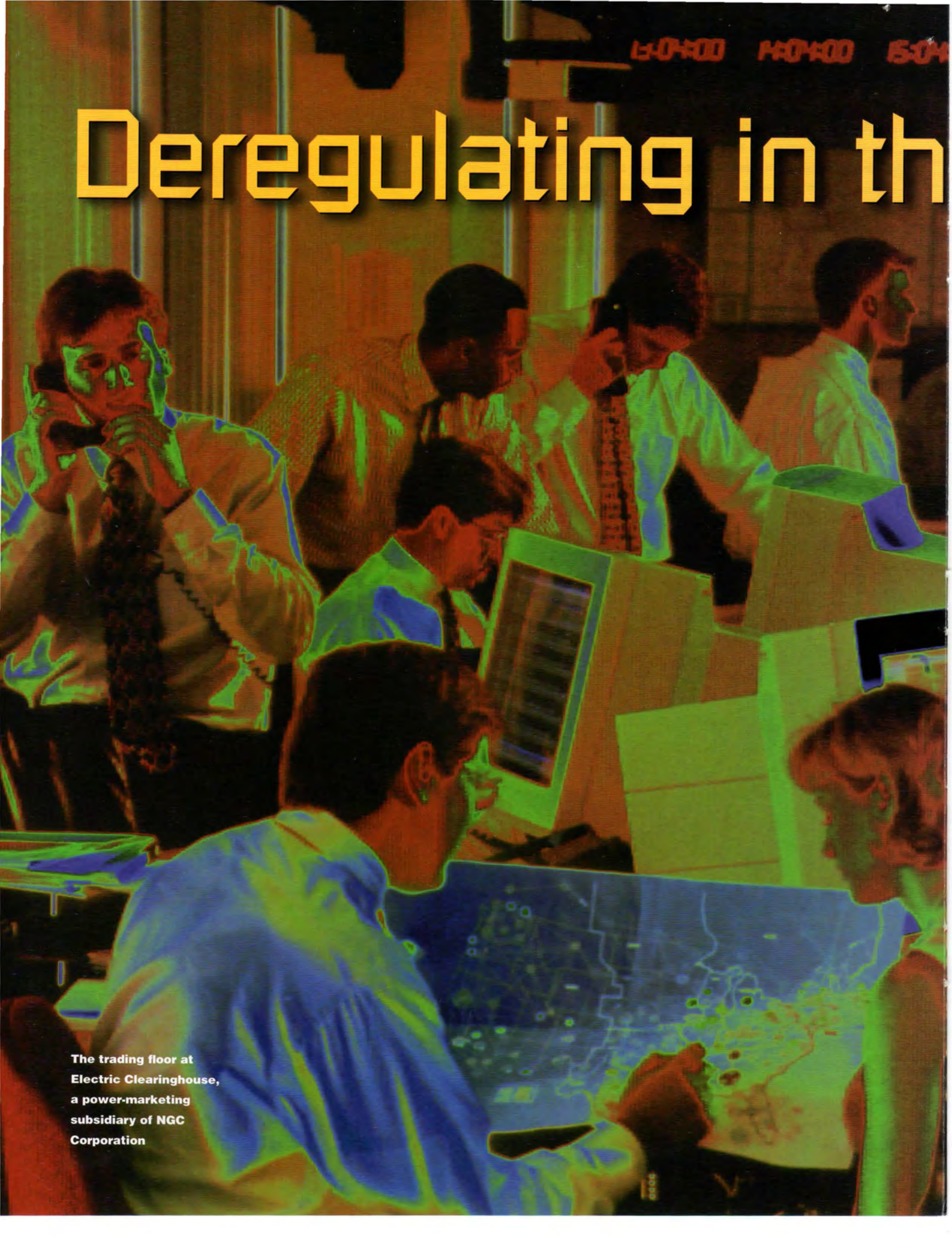


The trading floor at Electric Clearinghouse, a power-marketing subsidiary of NGC Corporation

e Information Age

ORIGINAL PHOTO COURTESY ELECTRIC CLEARINGHOUSE

THE STORY IN BRIEF

The electric power industry reached a major milestone under a tight deadline early this year with the launching of an Internet-based system for buying and selling power transmission services. Called OASIS, this system is the mandatory basis for such business transactions in the newly competitive market for transmission, supplanting the "old-fashioned" methods—faxes and phone calls. Business conducted on OASIS represents the biggest commercial use of the Internet to date. Now the challenge is to refine the system.

by Leslie Lamarre

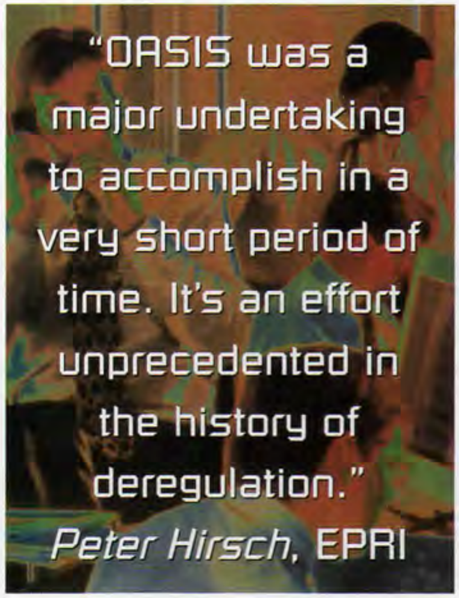
Dave Perrino stood before his colleagues in the electric power industry at a meeting in New Orleans this March and recounted technical problems and deicing procedures that had delayed his flight, getting him there at three o'clock in the morning. "This is similar to New York Power Pool's experience with OASIS," he told the crowd of 225. "It's up and running, but there are still some problems."

The comment drew some commiserating chuckles from the roomful of people, who'd been working frantically over the previous 18 months to launch OASIS, the Open Access Same-Time Information System, an electronic information network that is the basis for the newly competitive market for power transmission in the United States.

Commercially operating since January 3 of this year as required by federal mandate, the Internet-based OASIS (formerly called the Transmission Services Information Network, or TSIN) was designed to provide all buyers and potential buyers of power delivery and related services with equal access to transmission information. It presents information on available transmission routes, the capacity of these paths, and the fees for transporting power on these paths. Rather than using telephones and fax machines to negotiate paths and fees, customers must now log on to the Internet and access the OASIS Web site (www.tsin.com) or any of its 21 affiliated Internet nodes. The establishment of OASIS represents one of the electric power industry's first major steps toward a deregulated electricity market.

FAST WORK The electric power industry labored under very tight time constraints in developing and implementing OASIS. Starting with a blank slate in July 1995, the participants in this voluntary collaborative effort plowed through the complexities of the power transmission business and cleared several challenging technical hurdles to develop an Internet-based vehicle for transmission sales—all within 18 months.

As the comments of Perrino (who led the establishment of New York Power Pool's OASIS node) and other users indicate, it may be a while before OASIS provides a truly seamless medium for these transactions. But establishing the OASIS framework was a milestone in itself. "This was a major undertaking to accomplish in a very short period of time," says EPRI's Peter Hirsch, who oversees the Institute's extensive involvement in OASIS. "It's an effort unprecedented in the history of deregulation."



Indeed, electric utilities represent the first industry to deploy the Internet for fundamental business-to-business (as opposed to business-to-consumer) transactions. In so doing, they have launched the largest commercial application of the Internet, with billions of dollars in transmission transactions expected to occur this year alone.

Then and now

Before the passage of the Energy Policy Act of 1992, power transmission was more a consequence of power generation than a separate product in itself. As one power company employee puts it, "You scheduled energy and consumed transmission." For the most part, transmission dispatchers concerned themselves with delivering the utility's power to its own customers. Occasionally, during a period of unusually high demand or other extreme conditions, a neighboring utility would submit a request to move power over another utility's transmission system. Although utilities typically complied with such requests, they were not legally obligated to do so.

This scenario began to change with the passage of the Energy Policy Act, which gave wholesale power companies the right to wheel electricity over any utility's transmission lines for a fair price. Although some utilities started developing transmission tariffs, such action was not legally required until April 24 of last year, when the Federal Energy Regulatory Commission (FERC) issued Order 888. An accompanying order, 889, mandated the establishment of an electronic information network (OASIS) that would serve as the vehicle for communication between buyers and sellers of transmission services—even buyers and sellers within the same company. This rule also required the separation of utilities' power-marketing and transmission operations functions. As a result, employees who once worked side by side and communicated verbally now work either from separate parts of the same building or from separate locations entirely, communicating with each other electronically.

Although technically applicable only to public utilities, the FERC rules effectively apply to any power company that wants to do business with a public utility. "It's disruptive, but it's just something we have to do," Barbara Rehman, a technical spe-

OASIS development, 18 months

March 1995
OASIS concept born

July 1995
NERC's "what" group, EPRI's "how" group formed

October 1995
Industry's initial OASIS specifications

December 1995
FERC releases formal specifications

April 1996
FERC issues Orders 888 and 889

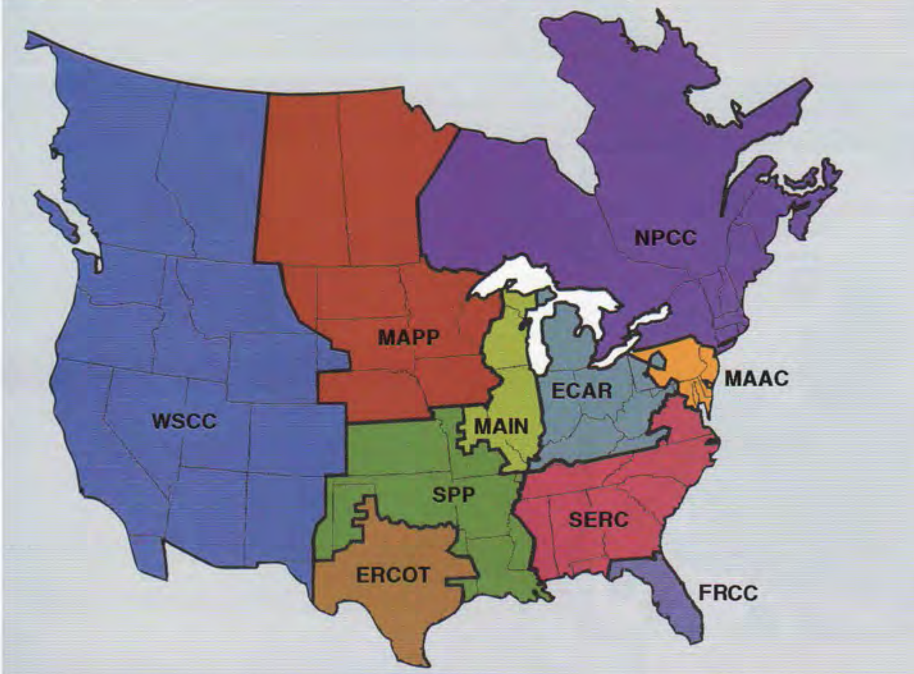
cialist with the Bonneville Power Administration, says of the separation requirement. This fall, BPA will relocate most of its transmission employees to an office near Vancouver, Washington, while power-marketing workers will remain at the utility's headquarters in Portland, Oregon.

FERC gave the electric utility industry advance warning of these changes through a notice of proposed rulemaking issued in March 1995, and it even encouraged participation in the development of OASIS. With this direct solicitation, the industry scrambled to define and design a system that would best deliver the goods.

Electric utilities, power marketers, independent power producers, and other industry players from across the country voluntarily came together to provide the technical feedback FERC requested. FERC appointed the North American Electric Reliability Council (NERC) and EPRI to facilitate two working groups—the "what" group and the "how" group—made up of these volunteers. NERC's group was charged with determining what information should be posted on the network. EPRI's group was to specify how those recommendations would be implemented.

Participants in the two groups strove for consensus among all the transmission providers and customers on the multitude of issues involved in defining the network. As could be expected, there was much interchange between the groups. "We had a lot of questions for the 'what' guys, and they had a lot for us," says EPRI's Hirsch. "They needed to understand how their recommendations would be implemented to be certain that they actually could be done."

Before long, it became clear that the system would rely on the existing public Internet as a communications network. An inexpensively accessible and widely available system, the Internet would enable users to readily obtain transmission information and download it to commercially available database managers, spreadsheets, and other applications. Says Hirsch, "To go from a blank slate to full implementation in such a short time frame would not have been possible without the Internet, and even with the Internet it was nearly impossible. But we did it."



NODES, NATIONWIDE **The North American Electric Reliability Council regions offer a rough guide to the location of the 21 Internet nodes that currently make up OASIS. These nodes serve as information hubs through which data flow between providers and buyers of transmission services.**

ECAR (East Central Area Reliability Coordination Agreement): ECAR OASIS

ERCOT (Electric Reliability Council of Texas): ERCOT OASIS

FRCC (Florida Reliability Coordinating Council): Florida OASIS Network

MAAC (Mid-Atlantic Area Council): PJM OASIS

MAIN (Mid-America Interconnected Network, Inc.): MAIN OASIS

MAPP (Mid-Continent Area Power Pool): MAPP OASIS

NPCC (Northeast Power Coordinating Council): NEPOOL OASIS, NYPP Transmission Providers

SERC (Southeastern Electric Reliability Council): Southern OASIS, VACAR OASIS

SPP (Southwest Power Pool): SPP OASIS

WSCC (Western Systems Coordinating Council): APS OASIS, ENX OASIS, Idaho Power OASIS, LADWP OASIS, Northwest OASIS, PacifiCorp OASIS, Puget OASIS, Rocky Mountain Area OASIS, SWOASIS, Western OASIS

Building OASIS

The result of these collaborative efforts is a backbone of 21 computer nodes—communications and information hubs for transmission providers and their wholesale customers—that stretches across the country. In the eastern and central United States,

July 1996
Industry amends specifications

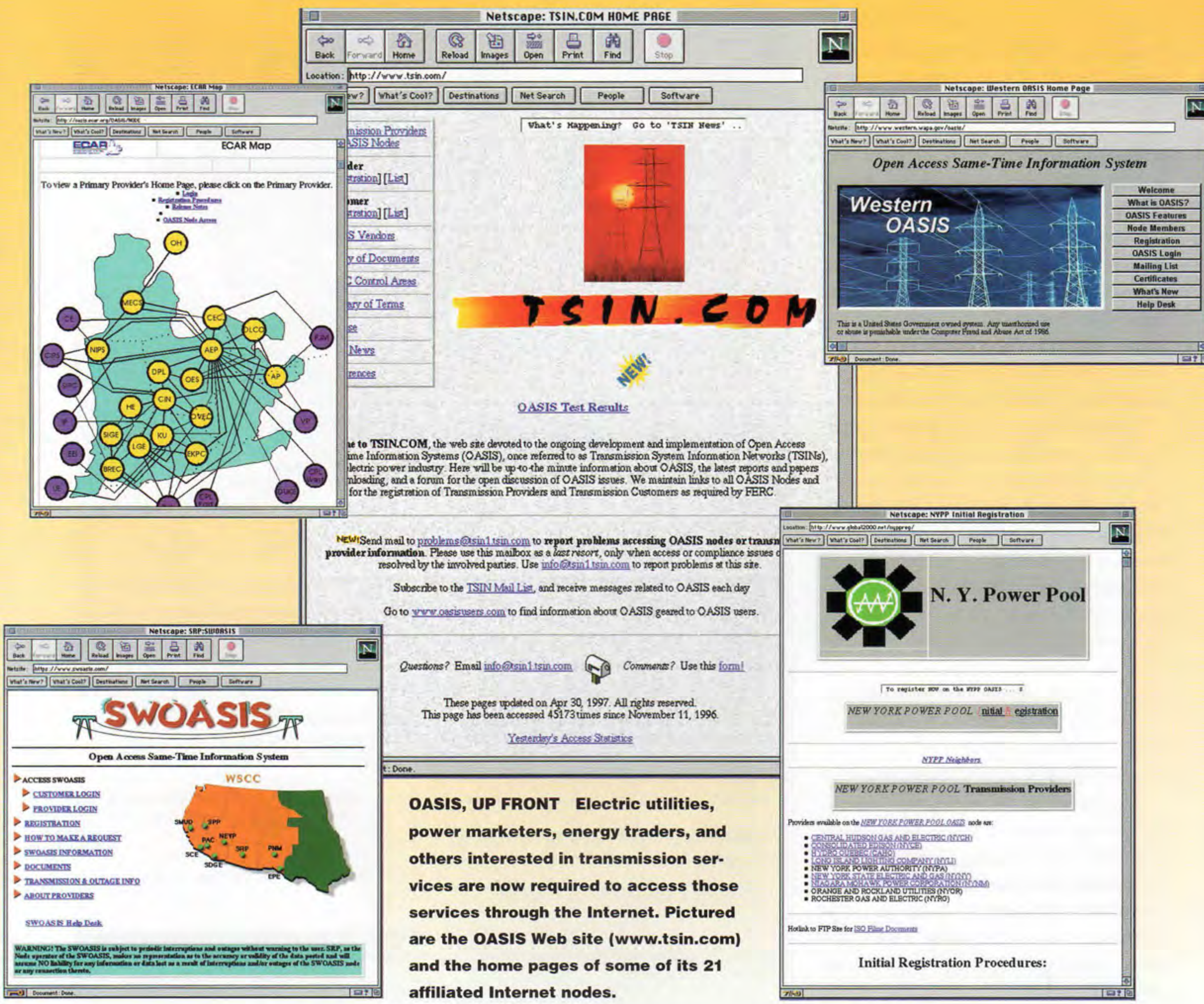
September 1996
FERC releases final specifications

December 1996
Industry starts testing OASIS nodes

January 1997
OASIS goes commercial

March 1997
FERC issues rehearing notice; NERC institutes compliance testing

1998
OASIS to be upgraded



OASIS, UP FRONT **Electric utilities, power marketers, energy traders, and others interested in transmission services are now required to access those services through the Internet. Pictured are the OASIS Web site (www.tsin.com) and the home pages of some of its 21 affiliated Internet nodes.**

the nodes generally correspond to the NERC regions established in 1968 to promote the reliability of North America's electricity supply. These nodes typically include data from several transmission providers. (The Mid-Continent Area Power Pool node, representing the upper Midwest and south central Canada, has the most providers, with 28.) In the West and Southwest, the nodes represent fewer providers—in some cases only one. "The number of nodes we wound up with was arbitrary," Hirsch explains. "We could have had as many as 200 of them. It was entirely up to the providers."

The reason for establishing multiprovider nodes was to pool resources and avoid duplication of efforts. Rather than creating and maintaining separate databases and servers to handle OASIS transactions, transmission providers feed their data into a shared node. One of the providers assumes responsibility for managing the node for the entire region.

Each provider is required to post on its node information about its services, including its existing transmission paths, their capability, and ancillary services like loss compensation, load following, and voltage control. When a potential buyer submits a request for any of these services, the request is posted on OASIS for others to see. All fees and discounts must also be posted. And to help ensure a truly open market for wholesale power, FERC has specified that there be no masking of users' identities on OASIS.

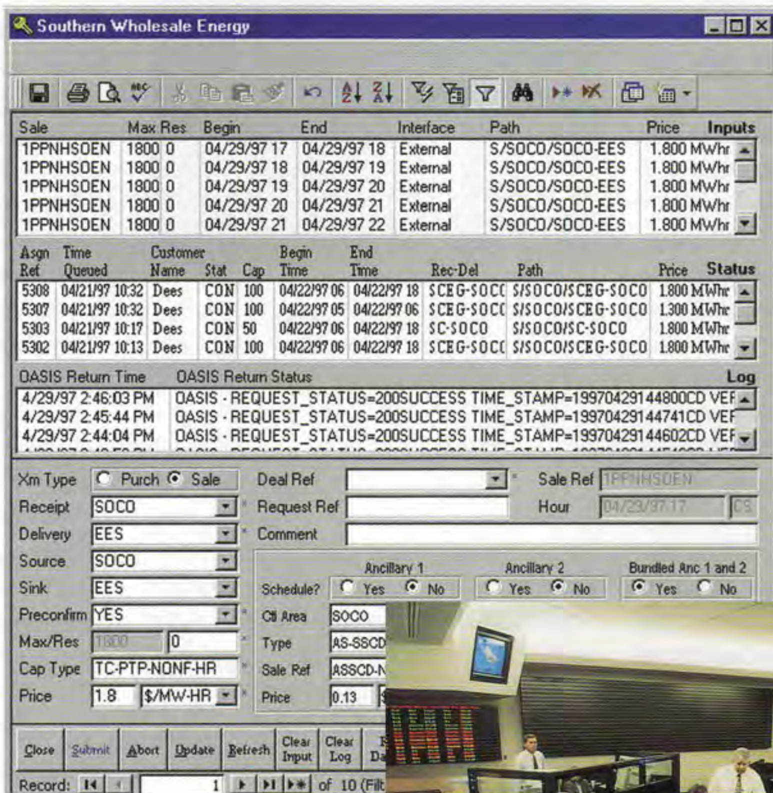
OASIS users who register, as required, with FERC can access the system's data with standard Web browsers. There are now roughly 350 registered OASIS customers—mostly utilities and power marketers—buying services from 172 registered providers. (Some users are both customers and providers, since they may buy transmission capacity from primary providers and resell this capacity to other firms.) At this time, the most active nodes are fielding hundreds of reservations daily, while the least active nodes are fielding dozens. Although most services (about 90%) are being sold in transactions between providers and buyers who were once part of the same organization, this figure is expected to decline rapidly and could be as low as 50% by the end of the year.

While the OASIS Web sites provide an interface for transmission customers, an entirely different interface is required on the back end, through which transmission providers field multiple requests over relatively short periods of time. Generally, back-end automation for calculating available transmission capability, billing, and scheduling is far more complex than front-end World Wide Web automation. EPRI's Hirsch draws an analogy to airline reservation systems. "It's one thing to make a reservation, but the actual filling of seats in the airplane and the billing for those seats are far more complicated matters that involve a lot of variables, such as weather, mechanical problems, and overbooking." And just as airline passengers may not wind up on the flights they originally booked, says Hirsch, "you may reserve a transmission line, but the transmission capability that is actually used may vary from that reservation."

Automating the back end of an OASIS reservation system so that accurate data get posted in a timely manner requires the development of special software programs to serve as interfaces between the OASIS system and the various information systems on the utility side. For instance, commitments made on OASIS for transmission capability must flow into a power company's energy-scheduling program (which tracks the dispatching of power plants) to be certain that transmission routes are not overbooked. Likewise, energy-scheduling data must flow back onto OASIS so that the resulting impact on transmission capability will be reflected in the publicly posted information on available transmission. Transmission providers that have not fully automated their back-end systems must perform analyses to determine transmission availability every time a request comes in. At the other extreme, a fully automated back-end system may require only that the OASIS operator click a single button to confirm a reservation, activate the billing system, and adjust energy-scheduling and other related data systems accordingly.

Typically utilities are either completing back-end automation themselves or hiring the vendors that developed the systems used to track transmission activities in their control centers. At this time, the automation of back-end systems is lagging significantly behind that of the front end. "I think people didn't anticipate how much work it would be to manage their transmission processes on the back end," says Gerry Cauley, a contractor representing NERC on the OASIS project. Adding to the challenge, last December FERC issued a letter clarifying that OASIS must be used for same-day and even next-hour business, which accounts for more than 80% of all transmission transactions. This caught many in the industry by surprise. The presumption had been that OASIS would not be used for such transactions—that same-day business would continue to be handled via phone and fax. "When this happened, the order of magnitude of stuff that has to be taken care of on OASIS went up by one notch," says Cauley. "It really threw a curveball into the whole process."

Fortunately, the more sophisticated back-end systems that are now under development will still be compatible with the front-end systems already being employed. But the lag in back-end automation is preventing some providers from offering complete and timely information on OASIS. "Just getting all of the providers and nodes up to a threshold level of performance is a key issue today," says Cauley.



DATA NAVIGATORS Some transmission service buyers have developed their own database management and application programs to navigate the river of data flowing from OASIS. Shown here is one of several templates created by Southern Wholesale Energy, a function of Southern Company Services, for reserving transmission and ancillary services.

COURTESY SOUTHERN WHOLESALE ENERGY

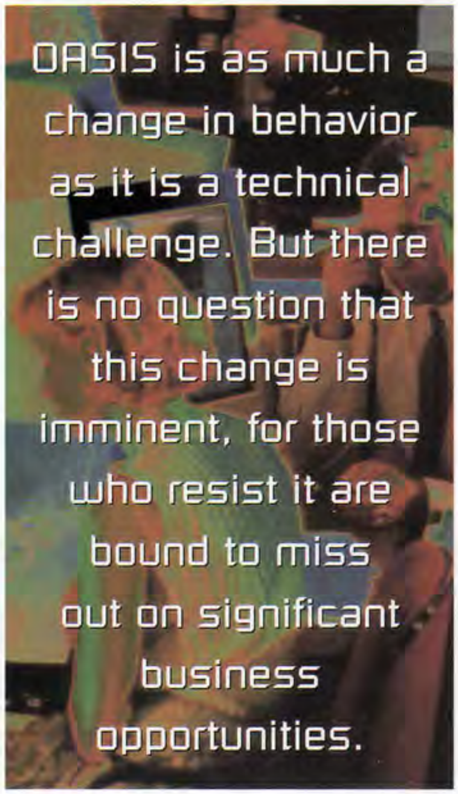
Marketing employees of Southern Wholesale Energy using OASIS

Bottlenecks

Contributing to the problems are information bottlenecks and system delays that can make downloading and even accessing data from OASIS nodes very time-consuming. John Henry, president of Power Navigator, an Internet-based information and communications services company headquartered in Washington, D.C., says that the problem is particularly apparent in multiprovider nodes. "We notice a big difference in response time," he says. "Downloading information from a single-provider node takes only 8 seconds. With multiprovider nodes, it takes more than 20 seconds. And if there are problems with a multiprovider node, access to all transmission providers in that node is cut off. The single-provider nodes are much more reliable." He predicts that increased competition in the industry will drive some multiprovider nodes to break up into single-provider subsets.

Transmission providers have their own set of gripes about companies like Power Navigator, which operates a Web site that synthesizes data from all OASIS nodes. Specifically, the providers complain that such users, who employ computer systems that automatically query OASIS nodes on a routine basis, are blocking lines that potential customers want to access. "They're hitting us so hard they're locking the system up," says Willie Wright, chief dispatcher for Nevada Power Company. "There are so many analysts out there trying to get information that we're missing opportunities to do business." A few utilities have resorted to software programs that target frequent queriers and shut them out after a certain number of hits within a specified period of time. Others are considering upgrading their OASIS servers to better field multiple queries. Many OASIS customers are also taking action by investing in private high-speed lines for better access to OASIS nodes.

Central to the complaints about OASIS performance is a debate about the system's reliance on the Internet. "We've come to the conclusion that any time you have the Internet involved in the loop, you're going to have a bottleneck," John Wolfrom of PJM Interconnection Association told his audience at the OASIS meeting in New Orleans in March. He said that transactions that take 3 seconds on his server take up to a minute on an Internet browser. (PJM manages an OASIS node for eight transmission providers on the East Coast.) Other critics point out the well-publicized problems of major Internet access providers like America Online—problems that have cut off millions of customers. Internet supporters counter that other network providers are available. Many also say the critics are mistaking a problem of inadequate OASIS servers for an Internet issue. "Some people started out using personal computers as OASIS servers for multiprovider nodes," says Stephen Garrett, who helped establish PacifiCorp's OASIS node. "Today's PCs just aren't powerful enough for this kind of application." Since that time, some of the PC users have upgraded to high-end workstation computers, and performance has improved accordingly.



Internet critics also question the security of the public Internet. They argue that any one of the Internet's 40 million users has an opportunity to break in, interfere with ongoing transactions, and wreak havoc on the nation's transmission grid. In contrast, they say, a private network, such as the Interregional Security Network (ISN)—a communications channel that NERC is developing to ensure reliability in the deregulated marketplace—would offer dedicated service for utility use, with ample security barriers. Internet supporters maintain that the firewalls and encryption built into the existing Internet-based OASIS system are just as secure. They also cite studies showing that nearly all computer break-ins are committed by employees and other insiders; break-ins of this type couldn't be thwarted by moving to a private network.

According to Cauley, OASIS is likely to maintain its Internet-based environment for at least two years—until the system has matured and sufficient experience has been accumulated to determine whether a move to a private network is necessary. Meanwhile, preliminary discussion has begun on the development of a separate electronic network that will track the generation side of the electricity business—that is, actual power purchases.

NERC is taking the lead in developing this so-called energy-scheduling system, and to ensure high performance, it has proposed that the network reside on a private intranet system that employs public Internet protocols. Cauley explains that the operational nature of the energy-scheduling business, as well as the fact that it involves the physical movement of power from generators to customer loads, calls for a dedicated network that won't be hampered by delays of any length. "With OASIS you've rented space on the transmission system," he says. "But when you schedule energy, you're essentially dispatching a generator to provide a specific amount of power at a designated time. If there's a mismatch between schedules and actual power flows, not only will somebody pay penalty dollars, but the misinformation could impact grid reliability." Ultimately, the energy-scheduling system will feed data directly into the ISN so that control room operators can track power flows and generators out of service to ensure the overall stability of the transmission grid. The system is slated to become active in 1998.

Making it work

Among the other challenges that have emerged in the early days of OASIS implementation is the need for standardization. The problem is that transmission providers posting information on OASIS are not necessarily using the same terms to represent the same services. While FERC has defined about a dozen basic transmission services to be posted on OASIS, at last count transmission providers were using some 250 different names to describe these services.

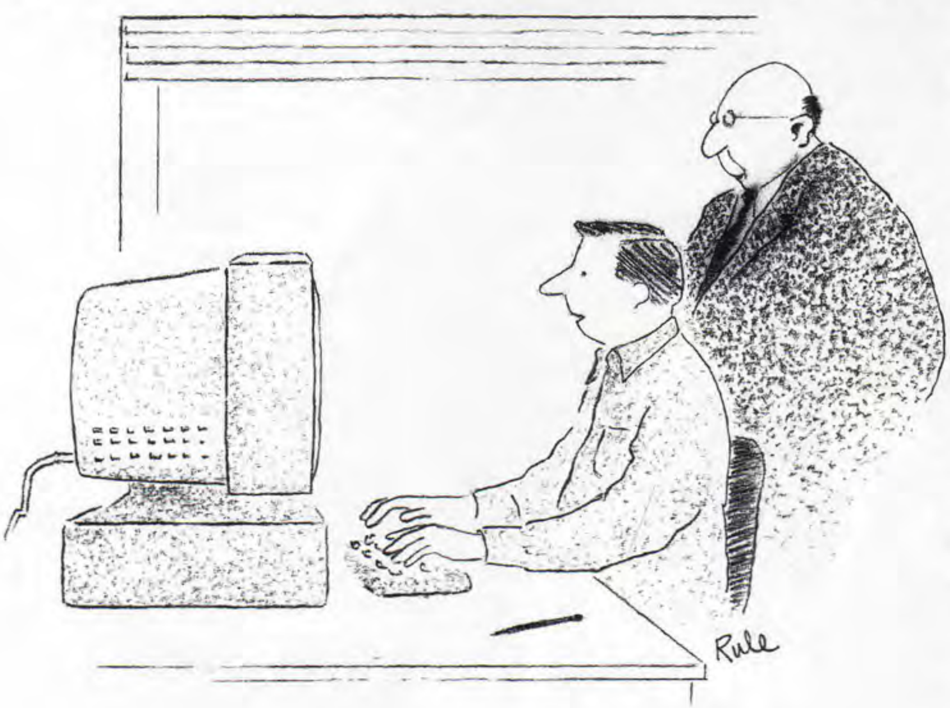
To encourage transmission providers to improve the overall functionality of the OASIS system, NERC began conducting routine tests of the individual nodes late in March. Through these tests, NERC determines whether all the nodes are in service and available, how well information is presented by the individual transmission providers in each node, and how much reservation activity each provider shows. Detailed results are posted on the OASIS Web site as a form of industry peer pressure to enhance OASIS. The tests will continue indefinitely.

Longer-term OASIS issues include the question of the so-called contract path. Currently the basis for ordering and paying for transmission, a contract path assumes that the power will flow in a direct line from one point to another. However, the concept of directing power along a designated path contradicts the laws of physics. Like water flowing through a piping network, electrons will follow the path of least resistance in a transmission system. By the time power flows from point *A* to point *B*, hundreds of miles away, it may very well have traveled through the high-voltage transmission networks of several utility systems. Some OASIS developers have questioned whether the system should employ a reservation process that more closely approximates actual power flow. A flow-based process would aim to get transmission revenue to the providers whose systems actually bear the load. (EPRI has developed computer models of the U.S. transmission grid that are capable of predicting—within 5–10%—actual transmission flow.)

At this time, however, there are more immediate OASIS issues to address, like getting customers to use the system for reserving transmission. A few transmission providers have learned that some of their smaller customers don't even have Internet access. And even for customers that are Internet proficient, the temptation of the telephone is hard to resist. Like consumers who would rather wait in line at a bank to make a deposit than complete the same transaction immediately at an ATM, such utility transmission customers don't entirely trust the technology yet. "PacifiCorp is still getting requests over the phone," Garrett noted at the OASIS meeting in March. In fact, he said, *most* of PacifiCorp's customers are using the phone. "We ask if they use OASIS and they say 'Yeah, well—no. Could you just do this for me?'"

Indeed, OASIS is as much a change in behavior as it is a technical challenge—a change that is not likely to occur overnight. But there is no question that this change is imminent, for those who resist it are bound to miss out on significant business opportunities. Some observers go so far as to say that the industry cannot truly deregulate without automating, simply because the volume of data coming from power companies—and being exchanged among the profusion of power marketers, energy traders, and other entities that have sprouted since the dawn of deregulation—is far too massive, and the pace too rapid, for human-to-human contact to manage. "Electricity is the quintessential information business," says John Henry of Power Navigator. "The commodity is real-time, so the only way the industry can deregulate is for computers to talk to each other."

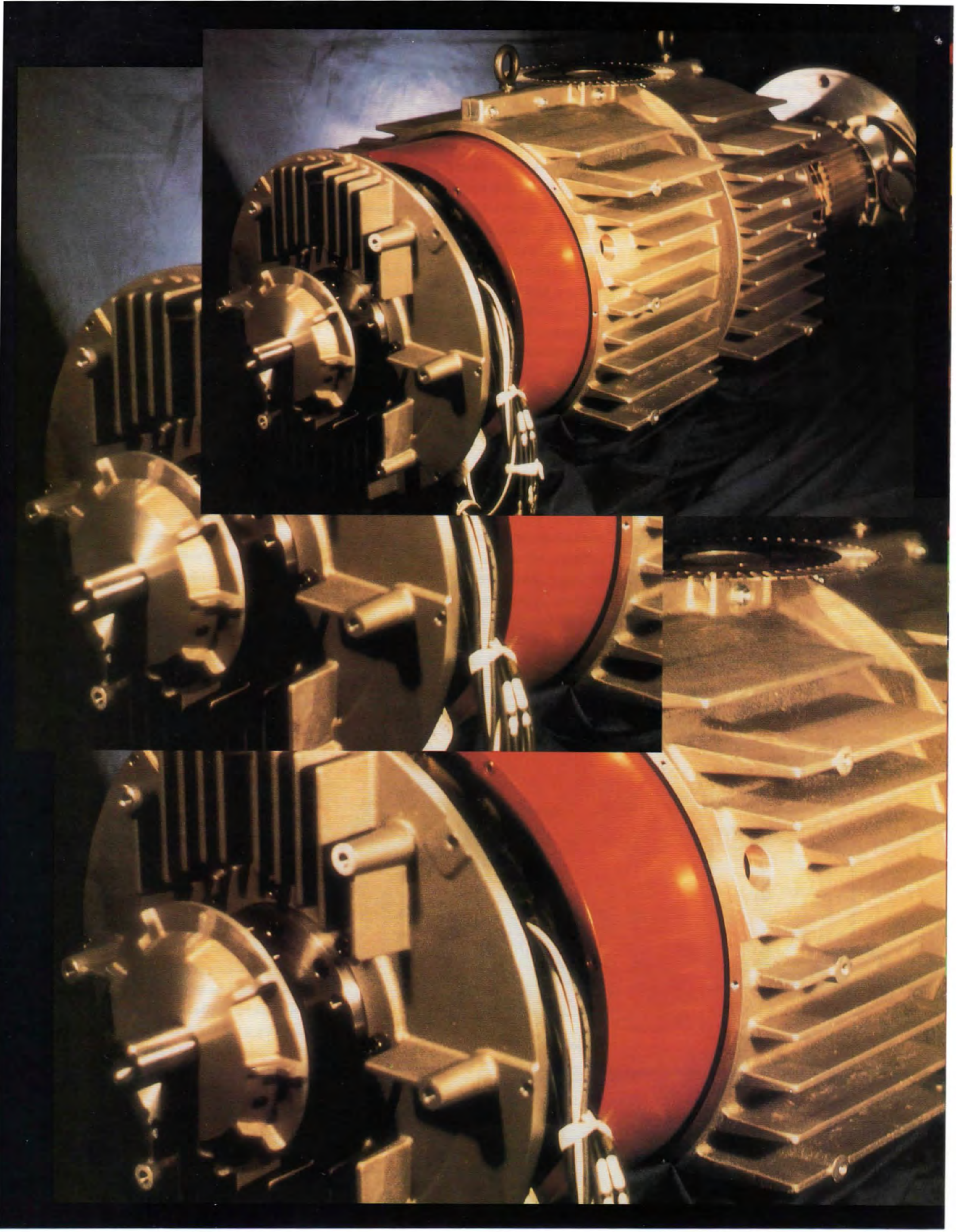
This may be true. But given the complexity of the power market and its transition into a deregulated business environment, another question looms: Is all of this effort in the name of a free market really worth it? FERC thinks so, estimating that competition will save consumers between \$3.8 billion and \$5.4 billion annually. Industry members see advantages too. "It's a good idea to open up the market," says Jagjit Singh of Salt River Project, who manages SWOASIS, the Southwest node. "I just think we're all in the learning phase, so we're probably stumbling a bit. But once people gain experience, congested areas will be identified and there should be improved utilization of the transmission system." ■



"IT SAYS IF WE BUY ANOTHER 50 MW, WE GET A FREE TOASTER."

CARTOON BY WENDY RULE

Background information for this article was provided by Peter Hirsch, Grid Operations & Planning Business Area.

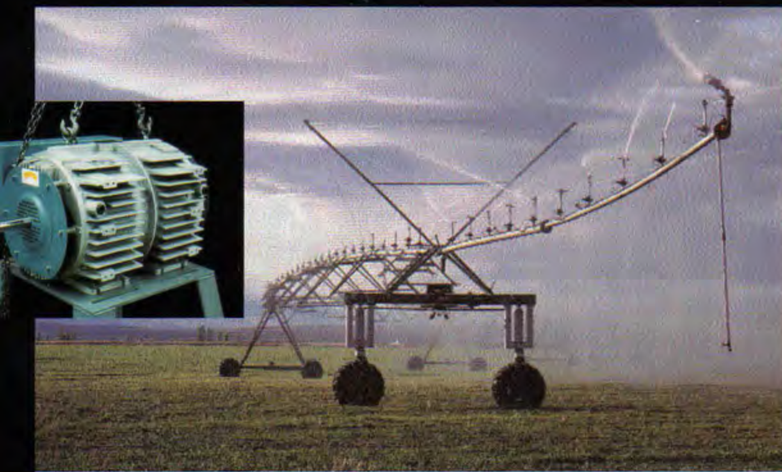


The Written-Pole Revolution

The Story in Brief The award-winning Written-Pole technology, developed with EPRI support, overcomes some fundamental drawbacks of conventional motors and addresses critical needs of electric power customers big and small. With an innovative design that adds unique flexibility to a motor's magnetic characteristics, the technology drastically reduces the need for a high starting current and increases reliability. Thus it is particularly valuable for remote and rural applications, where single-phase power is the norm. Written-Pole technology is also being deployed in motor-generator sets that can serve as uninterruptible power supplies, offering high-tech power customers with sensitive loads an alternative to maintenance-intensive battery systems.

COURTESY PRECISE POWER

by Steve Hoffman



INVENTED more than a century ago, electric motors pervade society today, running things as diverse as factory production lines and bedside alarm clocks. Collectively, these motors consume more than two-thirds of the electricity produced annually in the United States, with those over 5 hp (only 2% of all electric motors) accounting for more than 70% of the consumption.

While these larger motors have certainly increased our nation's productivity in applications ranging from irrigation to steel manufacturing, their conventional design has presented some challenges. One fundamental problem is that the motors require a very high current to start up—typically 6 to 10 times the current needed to maintain full-speed operation. For rural power customers with single-phase electric service, this means not being able to run motors over 16 hp without using expensive phase converters. For large industrial customers with three-phase service, it means the potential for power quality problems like voltage dips as large motors are brought on-line.

In the early 1980s, Precise Power Corporation—with EPRI support—developed a breakthrough technology to address these issues. Called Written-Pole™ technology, this patented approach uses innovations in magnetism to reduce a motor's need for a high starting current. In fact, a Written-Pole motor (WPM) typically requires a starting current that's less than twice its running current. Additional advantages are the motor's very high efficiency—92% in comparison with 85% for conventional motors—and its ability to ride through power interruptions of up to about 15 seconds. Also, WPMs can be combined with Written-Pole generators to offer an uninterruptible power source that's not dependent on maintenance-intensive batteries.

According to Precise Power, Written-Pole technology is the most significant development in motors in the past 30 years. Others agree: "The many benefits of these devices are good for our customers and good for us," says Dale Friesen of Manitoba Hydro, one of the utilities working most actively with Precise Power on the motors. In presenting the WPM a 1997 New Product Award, the National Society of Professional Engineers praised "its innovative use of engineering principles and materials and its overall benefit to society." The technology also won an R&D 100 Award from *R&D Magazine* in 1994, which recognized it as one of that year's 100 most technologically significant products.

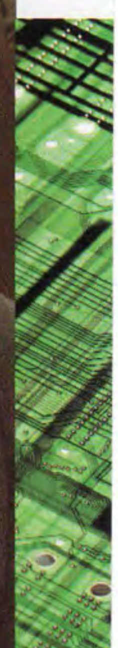


PHOTO OF OIL RIG BY FRANK WHITNEY/IMAGE BANK

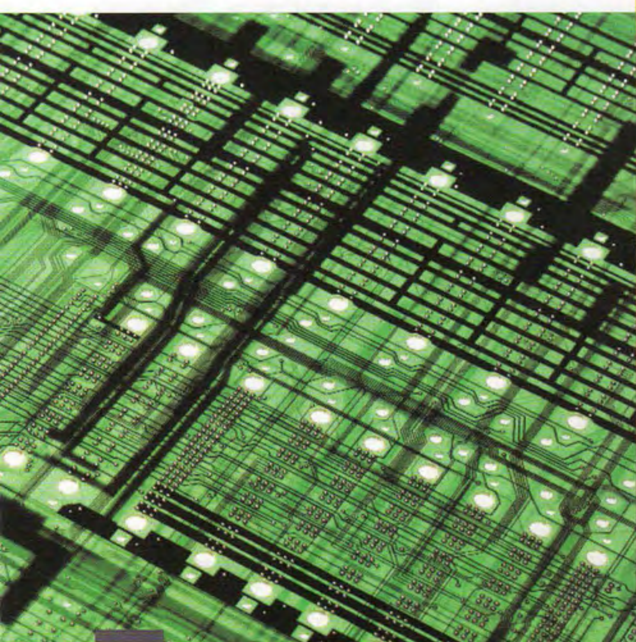
Together, EPRI and Precise Power have refined the technology and introduced the WPM and the Written-Pole motor-generator (WPMG) to the electric power industry. These devices are now being used by power producers and their customers throughout the world. "We've helped integrate this concept into the design of electric motors and generators," explains Ben Banerjee, EPRI's manager for advanced motors and drives. "The result is machines that help utilities and customers alike solve some of their most pressing problems."

How does it work?

As Michael Faraday demonstrated in 1821, two basic forces—electricity and magnetism—can work together to produce mechanical motion. This is the essence of the electric motor. The magnetic poles of conventional permanent-magnet motors are fixed in one position. In a WPM, the magnetic poles are more flexible; the technology incorporates a special coil that "writes" poles onto a ring of magnetic material attached to the spinning rotor. This coil operates in much the same way as a tape recorder, but instead of recording

RURAL APPLICATIONS In areas where only single-phase power is available, the Written-Pole motor is ideal for large-horsepower applications like irrigation, crop drying, sawmill operations, and oil pumping.

POWER QUALITY APPLICATIONS Written-Pole motor-generators provide an uninterruptible power supply that can protect substation circuit breakers, hospital equipment, computers, and other sensitive electronic hardware from power quality problems.



sound on thin magnetic tape, the pole-writing coil imprints a magnetic pole on a thick portion of the rotor.

Unlike a tape recorder, which is designed to only occasionally erase and rerecord sound, the Written-Pole coil writes and erases the magnetic pole 60 times per second (i.e., at a frequency of 60 Hz) during a motor's startup. And these poles alternate: first a north pole is written; then that pole is erased, and a south pole is written in its place. The alternating magnetic poles serve to pull the rotor forward much as a high current would, increasing the rotor's speed during each rotation until the motor reaches its full design speed. (A synchronous motor, the WPM is designed for an operational speed that is in sync with power line frequency.) When the full speed is achieved, the pole-writing procedure ceases and the poles remain as last written.

Written-Pole technology does not work on its own to start the motor. In fact, the technology is not even activated until the motor is brought up to 80% of its design speed by more-conventional startup technologies. One of these is the so-called squirrel cage (which, if named today, might be more aptly called the hamster's wheel). An essential part of many ordinary motors, the squirrel cage is typically made of a low-resistance material so that it does not lose energy at full speed. The WPM employs a squirrel cage made of high-resistance material, which allows it to be activated by a much lower starting current. In the meantime, an effect called hysteresis (a phenomenon that some small synchronous motors, such as those in household clocks, also make use of) helps increase the torque required to get the motor up to 80% of its design speed. At this point, the Written-Pole technology is activated to complete the startup.

Because the WPM involves a lower starting current and lower torque than conventional motors, it takes longer to come to full speed. Whereas the high current and high torque of conventional motor technology would have a heavy load up and running within seconds, a WPM may take 1 to 5 minutes to start the same load. A brisk startup is actually mandatory for conventional motors, since the high internal temperatures generated by the elevated current and torque could very well burn out a motor that fails to start a heavy load within about 20 seconds.

In contrast, the lower starting current of the Written-Pole technology means that less heat is generated and a longer startup time is possible. As a result, the WPM can start loads more than 10 times as heavy as those that can be started by conventional induction motors of the same size. The gentler effect of the lower current and longer startup enhances the WPM's reliability and can extend its life to just about double the life of conventional motors. Another advantage of smoother operation is the mitigation of water hammer, a damaging phenomenon that can occur in pumping applications. In addition, a WPM's big, heavy rotor has great inertia, which makes the motor as difficult to slow down as to start up and thus helps it ride through power disturbances as long as 15 seconds. In contrast, a conventional motor will grind to a halt if an interruption lasts more than a second.

If the inertia is not needed for some applications, WPMs can also be made with lightweight rotors that enable them to start and stop at the same rate as ordinary motors. This type of WPM will still have a low starting current and high efficiency, as well as the ability to start heavy loads.

	Written-Pole Motor	Conventional Motor*
Efficiency (%)	92.4	85.0
Power factor	1.0	0.905
Starting current (A)	218	1160
Ride-through capability (s)	15	0.1
Maximum connected inertia (lb-ft^2)	580	40

*Three-phase motor operated via a rotary phase converter.

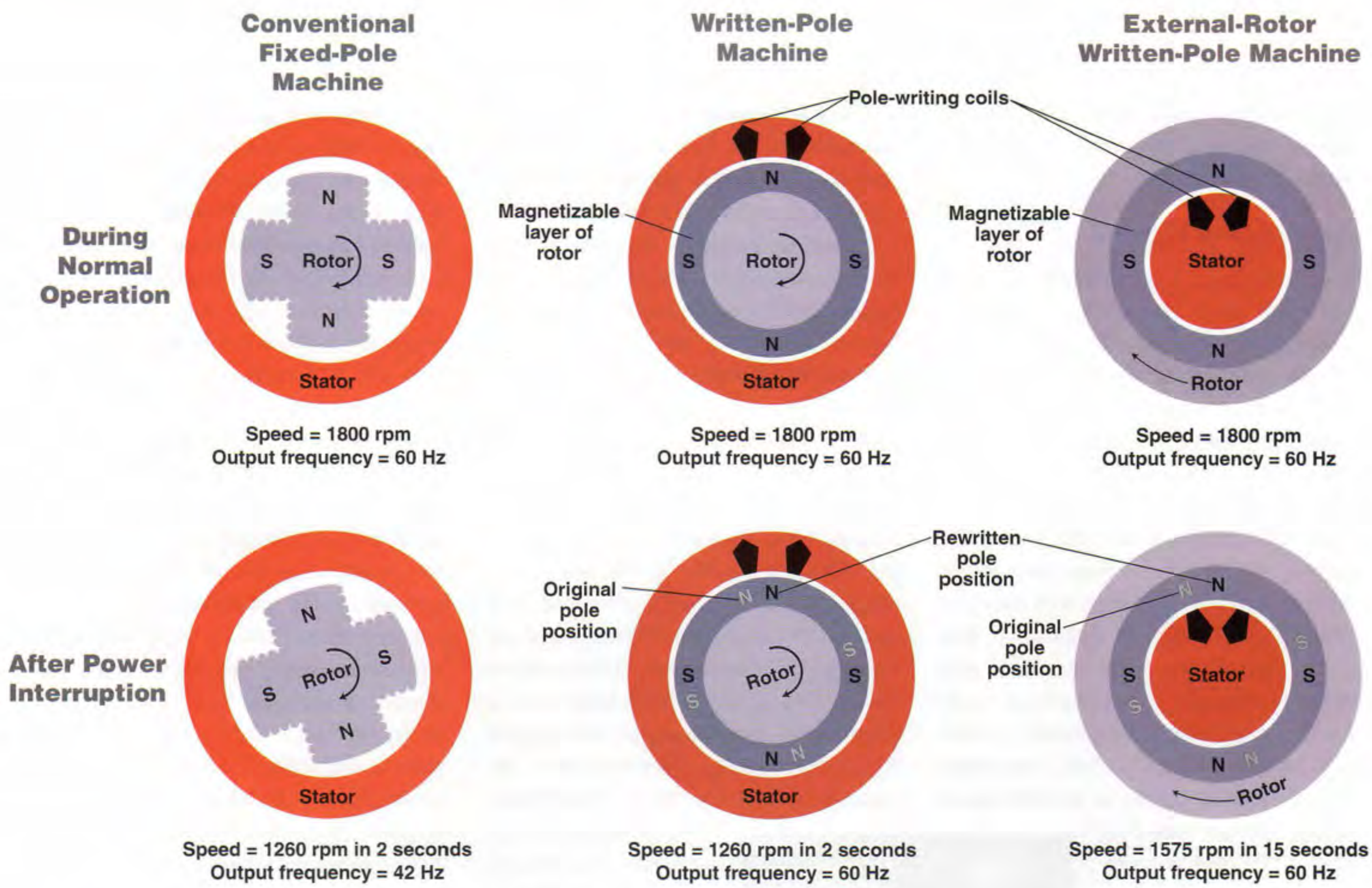
SOLUTION TO A REMOTE PROBLEM Single-phase motors over 16 hp can severely strain the single-phase distribution systems common in rural and remote locations. One alternative for large-motor applications in these areas has been to couple a three-phase motor with a rotary phase converter that allows it to use single-phase power. Comparing the performance of such a machine with that of a Written-Pole motor (both 40 hp) shows why the new technology is making inroads in rural applications.

Rural role

A number of rural power customers are already benefiting from Written-Pole technology. In contrast to urban and suburban areas, which are served almost exclusively by three-phase distribution systems, rural areas by and large have single-phase service. This can create a problem for customers who need to run large motors for applications like irrigation, oil pumping, sawmills, and municipal water-pumping systems. That's because motors over 16 hp involve such a high starting current that they typically will cause voltage sags and equipment shutdowns on single-phase distribution systems.

One way around this problem is to adapt three-phase motors to single-phase power by using phase converters, but this is expensive for the customers. Another solution, running three-phase distribution lines to these customers, can be prohibitively expensive for utilities—more than $30,000 per mile. Hence farmers, operators of small water systems, oil well operators, and others in rural or remote areas have resorted to using costly internal combustion engines instead of electric motors.

The WPM provides a lower-cost solution. Because of its lower starting current, the WPM can drive single-phase loads of up to 60 hp without straining single-phase distribution systems. "The WPM's low starting current has a soft impact on single-phase distribution lines," explains Mike Cherry of South Carolina Electric & Gas Company, who has worked with several customers to install the machines. "That's why 30- or 40-hp motors can be used on existing weak single-phase systems. Utilities can save a ton of money if they can avoid three-phasing distribution lines to serve motor loads. In our case, we saved $20,000 by serving a small town with a 30-hp pump using the existing number 8 copper single-phase line."



DEALING WITH A POWER INTERRUPTION In a conventional generator, the internal rotor must spin at a fixed speed, such as 1800 rpm, to give a steady output frequency of 60 Hz. Two seconds after a power interruption, the speed of the conventional rotor has decreased to about 1260 rpm. Since the positions of the rotor's magnetic poles are permanent, when the rotor "falls behind," the output frequency drops to 42 Hz—enough to disrupt even the most robust equipment in use today. Although the rotor speed of the Written-Pole generator also decreases after a power interruption, the generator's pole-writing coils can "rewrite" the north and south poles on the magnetizable layer of the rotor 60 times per second. Essentially, the coils position the poles where they need to be to maintain a 60-Hz frequency, thus avoiding disruption of loads. Configuring the generator with an external rather than an internal rotor increases its inertia without adding extra weight. This results in a longer ride-through capability—15 seconds at full load and constant frequency.

Other advantages for power producers and distributors include new electricity revenues, new service opportunities, and customer retention. Western Resources realized such benefits when its Westar Energy subsidiary helped a customer install a WPM in a single-phase application in a Kansas stockyard (*EPRI Journal*, March/April 1997, p. 34). "Cost-effectively meeting our customer's needs was made possible by this new motor," says Westar's Carl Miller.

Rural electric cooperatives—which own and operate about half of all the miles of distribution line in the United States, much of which is single-phase line—are major advocates of WPMs. "Written-Pole machines allow our members to serve large motor loads without expensive line upgrading," says Martin Gordon of the National Rural Electric Cooperative Association. Through its Rural Electric Research Program, NRECA has been one of the largest contributors to EPRI's work on this technology.

Southwest Arkansas Electric Cooperative Corporation is among several NRECA members to employ WPMs. "In one case, we had a farm located 17 miles from the nearest substation and 7 miles from the nearest three-phase line," explains the cooperative's Alan Hannah. "Rather than spend an estimated $210,000 to run three-phase service to this customer, we worked with NRECA and the customer to install a 20-hp WPM and centrifugal pump to flush swine houses and irrigate pastures. The technology is another tool that distribution engineers can use to better serve the needs of rural electric customers."

To determine likely rural end-use applications for Written-Pole technology, EPRI turned to the National Food and Energy Council, an organization that deals with agricultural and rural-related applications of electricity. "We knew that the largest market for this motor was irrigation, but we soon found that oil pumps, crop-drying fans, and pumps for rural water districts and wastewater treatment were also good applications," says the council's president, Richard Hiatt. "We are now demonstrating a 30-hp motor on an irrigation pump and have partnered with EPRI to become a resource center for Written-Pole motor information."

Big-customer benefits

The WPM's lower starting current and high efficiency make it attractive for three-phase applications too. For industrial customers with heavy loads, conventional motors can draw so much current during startup that they cause voltage to dip, and that can disrupt other electrical equipment operating at the same site. Worse yet, the more efficient the motor, the higher the current required for startup. As a result, industrial power customers who have upgraded to more-efficient motors may find that they have to resize the wires and switches throughout their facilities in order to accommodate the increase in starting current. Typically such customers might consider buying a variable-speed starter for the motor to resolve the problem, but such starters are expensive. In fact, a WPM and its accompanying starter would be about half the cost of a special variable-speed starter–motor combination.

"An attractive option for customers with loads that are sensitive to power quality disturbances is to combine WPM technology with Written-Pole generator technology to create a WPMG," says Marek Samotyj, manager of EPRI's Power Electronics End-Use Systems Business Area. "The result is an uninterruptible power source that's not dependent on batteries."

In this country, virtually all power interruptions are caused by fault-clearing operations on utility distribution systems—circuit breakers opening briefly and closing to clear faults. Such disturbances may last less than a tenth of a second and have little impact on noncritical loads like home appliances and commercial lighting. But they can seriously disrupt sensitive electronic equipment like computers and adjustable-speed drives. The result can be devastating in terms of downtime and lost products. Estimates of the cost of power quality complications to U.S. manufacturers have run as high as $26 billion annually.

Protecting sensitive equipment from these interruptions is beyond the capabilities of conventional motor-generators. During a modest voltage sag or other momentary power disruption, conventional motor-generators immediately begin to slow down. When this happens, the magnets in the machine rotate fewer times per second, causing the generator's output frequency to drop. Typically, within 1 second the output voltage begins to dip. For this reason, critical loads are usually protected by a more reliable source, battery-supported uninterruptible power supply (UPS) systems. These systems, which use a large bank of batteries for energy storage, have logged billions of hours of operating time. Because batteries are prone to failure, however, it requires a lot of maintenance to keep UPS systems reliable.

The WPMG provides reliable protection for sensitive loads without the use of batteries. Here's how it works: Connected to the utility line, the motor powers the generator. As the motor is affected by a disturbance and begins to slow, the generator senses the change in speed and its Written-Pole technology kicks in, writing alternating magnetic poles at a 60-cycle rate to maintain the frequency and voltage. Like the stand-alone WPM, the motor in the WPMG set is built with a heavy rotor that helps it hold output voltage and frequency constant for 15 seconds at full load and 1 minute at partial load. This length of time is sufficient to ride through 99% of all power interruptions.

Written-Pole motors under construction

PHOTOS COURTESY PRECISE POWER

Although a stand-alone WPM can ride through disruptions of the same length on its own, it will start to slow. If the motor powers mechanical operations—for instance, water pumping—the effect is simply a slower rate of work. But more-sensitive electronic equipment can be misdirected or even shut down by the briefest power disruption. By maintaining full frequency and voltage during power disturbances, the WPMG effectively isolates the sensitive equipment from the utility load and provides clean power. An engine fired by diesel fuel, natural gas, or propane can be added to the WPMG configuration to maintain voltage and frequency during outages lasting longer than 15 seconds.

Sensitive loads

Many tenants of downtown Manhattan's Silicon Alley rely on equipment sensitive to momentary power interruptions. "The multimedia information and entertainment companies in this area demand very high levels of power quality and reliability," says Frank Sinicola, power quality engineer at Consolidated Edison Company of New York, "and we're going to give it to them." Working with New York City and the Alliance for Downtown New York, Con Edison is seeking to maintain its reputation for top reliability. At the same time, the utility wants to lower the 21% vacancy rate in Manhattan office buildings. One way to do this is to provide services like ultrahigh-quality power. The 25 high-tech tenants of the New York Information Technology Center at 55 Broad Street are now benefiting from three 35-kVA WPMG sets that protect computers and other equipment from voltage dips. "With the new motor-generators, our customers are happy, so we're happy," says Sinicola.

High-quality power is also needed in harsher operating environments. Techneglas of Pittston, Pennsylvania—a customer of Pennsylvania Power & Light Company (PP&L)—manufactures glass for the front end of television picture tubes. In the furnaces used to produce optical glass, a temperature change of a few degrees resulting from the momentary interruption of stirring motors can spoil enormous quantities of glass. Similarly, an interrupted furnace mechanism can cause expensive damage with a long repair time. Although a variety of power-conditioning equipment is commercially available, without expensive enclosures most would not function properly for long in the glassmaker's environment.

PP&L had already reduced momentary power disturbances on its system to a few per year. But since each such event could cost Techneglas several hundred thousand dollars, the glassmaker wanted the ultimate in power conditioning—a rugged system that would provide isolation from the electrical system during all momentary power disturbances. To achieve this, Techneglas installed twelve 35-kVA WPMGs that operate around the clock on targeted critical loads, such as controls for the furnace, hydraulic system, and pumps. This approach eliminates outage costs, reduces waste, and improves productivity.

"The higher-quality power and energy savings utilities can offer with the Written-Pole products will help retain customers," says Clark Gellings, EPRI vice president for customer systems. "We are extremely proud of being involved with this technical achievement."

Moreover, a number of electric utilities are enjoying the benefits of Written-Pole technology themselves. At Public Service Electric and Gas Company's Mercer station in Trenton, New Jersey, obsolete generator excitation systems were replaced with a state-of-the-art solid-state system. But this upgrade inadvertently raised a potential problem. Interruption of the new excitation system for even a few cycles would cause a generator trip, necessitating a time-consuming and expensive restart. The trouble stemmed from the fact that a routine switching process between normal and auxiliary buses causes a momentary power interruption of up to 45 cycles (three-fourths of a second) each time the generators are started. After considering several possible solutions, the utility decided to use three redundant WPMGs. Now during the bus transfer, the rotational energy stored in the WPMGs' spinning external rotors (called flywheel energy) provides uninterrupted power, avoiding a generator trip.

PHOTO COURTESY THE RUDIN FAMILY

PROVIDING PREMIUM POWER High-tech companies in downtown Manhattan's Silicon Alley need extraordinary power quality to keep ultrasensitive electronic equipment running glitch-free. Consolidated Edison Company of New York is using Written-Pole motor-generators to provide such service for one of its customers, the New York Information Technology Center at 55 Broad Street. The three 35-kVA WPMG sets installed there protect a range of computers and other sensitive equipment from momentary power interruptions.

A rural electric utility in Marietta, Georgia—Cobb Electric Membership Corporation—is among those that have demonstrated use of the WPMG with engine backup. The utility operates a power control center to manage power distribution to its customers. "We use a complex AM/FM mapping system, management controls, and critical computer systems in the dispatch center," says Cobb's Bill Rouse. "The WPMG with diesel generator backup that we installed as part of our new operation and engineering facility provides continuous, clean power to the center."

While most WPMG applications produce ac power, the WPMG is equally adept at producing output power for dc loads. For example, in a substation or a power plant, dc power is required for circuit breakers and other controls in the event of a power interruption. Traditionally batteries provide this power, but the combination of a WPM and a dc Written-Pole generator can do so at a lower operating and maintenance cost. Such WPMGs can also enable utilities to serve aging dc loads—for example, the dc-powered elevators still in use in some older metropolitan areas—at a lower O&M cost.

Other applications

U.S. hospitals are beginning to deploy WPMGs to ensure a smooth transfer to their emergency power supplies. This provides peace of mind at these medical facilities, which depend on a dizzying array of critical electronic technologies—including CAT scanners, MRI devices, and nuclear medicine equipment—that are sensitive to power disturbances. At St. Francis Hospital in Indianapolis, four WPMGs are now

Benefits for Developing Countries

By taking advantage of single-phase electrification, Written-Pole motors (WPMs) have the potential to improve the quality of life in many parts of the developing world.

Most developing countries prefer single-phase service, which costs about half as much as three-phase service because it uses less copper and less pole hardware and is easier to install. These cost savings mean that for a given budget, twice as many people can be served by single-phase service as by three-phase service. However, rural applications like water pumping for irrigation and village water supplies typically require motors ranging in size from 10 to 40 hp. Because of their high starting current, conventional motors in this size range place considerable voltage strain on single-phase electrical systems. As in rural areas of the United States, WPMs can solve this problem by minimizing the starting current. The benefits include dramatically improved crop yields, access to cleaner underground water for drinking, and—as a result of crop drying—reduced crop spoilage.

According to Tim Hennessy of the South African utility ESKOM, low-cost rural electrification is of increasing importance to the country's electric utility industry. ESKOM alone is electrifying over 300,000 homes a year in an effort to extend the benefits of electricity to the 60% of South Africa currently without it. "For single-phase service, there's simply no competition with the Written-Pole motor," said Hennessy during a recent U.S. visit to evaluate the purchase of more of the motors. ESKOM has already demonstrated several 50-Hz WPMs, some in sugarcane and hops irrigation applications. And, Hennessy added, "for three-phase use at or near urban centers, the Written-Pole motor is the only way to go for larger-horsepower end uses." Among other benefits, ESKOM has found that the motor helps protect against the numerous voltage sags that result from lightning, which is more prevalent in some areas of South Africa than anywhere in the United States.

PHOTO BY GUY STUBS/THE MVULA TRUST

The WPM also presents investment opportunities for domestic utilities and service providers in developing countries like India, China, and Brazil. With motor purchase cost the critical consideration, an internal-rotor variation on the WPM design is likely to make inroads in these markets. Although this variation sacrifices ride-through capability because of the internal rotor's smaller inertia, the lower-tech loads these motors will drive are more able to tolerate momentary power disruptions. The internal-rotor design is likely to be even less expensive to manufacture and slightly more efficient than its external-rotor counterpart. □

operating. They allow critical equipment to stay on-line during the 10 seconds required to start the backup generators, so the hospital can make a smooth connection to emergency power.

Another WPMG user in the health care industry, Dade International, provided an unlikely service during Hurricane Hugo in September 1989. As the storm pounded Puerto Rico, almost all power generation was interrupted, virtually cutting off communication with the island. But a WPMG and backup engine installed earlier at a Dade facility in Aguada to protect its computer network and blood analyzers remained on-line throughout the crisis, providing the island with a source of power for critical satellite communications.

In another application, researchers at the National Institute of Standards and Technology are using a WPMG to protect sensitive equipment like the nuclear analytical instruments they use to track lead absorption in humans over time. WPMGs are also enhancing everyday public safety by ensuring uninterrupted power to the Federal Aviation Administration's Doppler and NEXRAD radar systems for weather anomaly surveillance. And at the University of Florida in Gainesville, two 35-kVA WPMGs with engine backup provide uninterrupted power to instrumentation and controls in the Microkelvin Laboratory. Continuous experiments for as long as 18 months are needed to achieve the laboratory's stated goal of attaining the lowest recorded temperature in the universe (one-millionth of a Kelvin).

A wide array of other applications of Written-Pole technology are in the works. For example, researchers say, the technology can be used to overcome the voltage drop characteristic of distribution lines strung in deep mines. Also, researchers expect that soon Written-Pole machines will move beyond the commercial sector and enter the residential market segment of larger homes. And they predict that the technology will provide uninterruptible power for remote medical diagnostic systems and will be deployed to back up wireless personal communications service systems soon to hit the market. "There's something here to please everyone," says EPRI's Banerjee, "from power producers to distributors to consumers like you and me." ■

Background information for this article was provided by Ben Banerjee and Marek Samotyj of the Power Electronics End-Use Systems Business Area.

CONTRIBUTORS

Technical sources for Journal feature articles

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Market Potential High for Fuel Cells (page 6) was written by Taylor Moore, *Journal* senior feature writer, with assistance from three members of EPRI's Generation Group.

Dan Rastler is manager of the fuel cell and distributed power program in the New Generation Business Area. He joined EPRI in 1981 as a project manager for fuel cell systems. Previously he spent five years with General Electric Company's Nuclear Energy Division, four years in the U.S. Air Force, and one year with Toscopetro Corporation. Rastler received a BS in chemical engineering from the University of California at Davis and an MS in mechanical engineering from UC Berkeley.

Rocky Goldstein has managed fuel cell R&D since he joined the Institute in 1985. Previously he worked for 24 years at International Fuel Cells, which originally was the Power Systems Division of United Technologies Corporation. After joining UTC's Pratt & Whitney subsidiary in 1961, Goldstein worked on numerous fuel cell projects for space missions, including the Apollo program, and for ground-based applications. He received a BS in physics from Northeastern University.

Arthur Cohn is manager for advanced-cycle power plants in the New Generation Business Area. He has also managed work in fusion and coal gasification since joining the Institute in 1974. Earlier, Cohn worked for Cambridge Research Laboratory, Avco-Everett Research Laboratory, and Pratt & Whitney. He earned SB and SM degrees from the Massachusetts Institute of Technology and a PhD in electrical engineering from Rensselaer Polytechnic Institute. ■

Deregulating in the Information Age (page 18) was written by Leslie Lamarre, *Journal* senior feature writer, with background information from **Peter Hirsch,** manager for power systems engineering in the Grid Operations & Planning Business Area of EPRI's Power Delivery Group. Hirsch is responsible for facilitating the OASIS "how" working group. He also manages work on EPRI's TRACE software for calculating transmission capacity and on the Power System Analysis Package, or PSAPAC, a set of tools for transmission grid planning. Before joining the Institute in 1992, Hirsch spent 26 years with IBM Corporation, ultimately serving as manager for advanced systems at the IBM Scientific Centers. He holds a BS in mathematics and physics and MS and PhD degrees in mathematics, all from the University of Wisconsin. ■

The Written-Pole Revolution (page 26) was written by science writer Steve Hoffman with assistance from two members of EPRI's Customer Systems Group.

B. Ben Banerjee, power quality and power electronics end-use team leader, joined EPRI in 1985 as a senior project manager in the Industrial Program and in 1989 moved to the Power Electronics & Controls Program. Before coming to the Institute, he was engineering manager for Square D Company. Banerjee holds a BS in electrical engineering from the University of Calcutta and an MS in the same field from the University of South Carolina.

Marek Samotyj manages the Institute's Power Electronics End-Use Systems Business Area and also its joint target on power quality. He joined EPRI in 1985 after a year as a consultant working on Institute power electronics systems projects. Previously Samotyj was a research assistant with the Energy Modeling Forum at Stanford University for three years. Still earlier, he held several consulting positions in Poland, including one as an engineer for the Polish Ministry of Mining and Energy. Samotyj holds bachelor's and master's degrees in electrical engineering from Silesian Polytechnic University and an MS in engineering-economic systems from Stanford University. ■

UV lamps in a hospital setting

PHOTO COURTESY MEMPHIS LIGHT, GAS AND WATER DIVISION

Real-World Test of Ultraviolet Air Disinfection for Controlling Tuberculosis

After more than four years of planning, a project to determine the efficacy of ultraviolet air disinfection for controlling the spread of tuberculosis got under way in New York City on May 22. This study, which is expected to last five years and to take place in six cities, is being conducted by investigators from St. Vincent's Hospital and Medical Center of New York, EPRI, Consolidated Edison Company of New York, Harvard School of Public Health, Harvard Medical School, and Tulane University.

Tuberculosis, which is spread when a healthy person inhales bacteria coughed into the air by an infected person, has made a strong comeback in the United States over the past 15 years. Today TB is recognized as a major threat to public health.

Ultraviolet air disinfection has potential for controlling diseases like TB because it can destroy the DNA of airborne infectious organisms on contact. This capability was first demonstrated in studies at Johns Hopkins University in the 1940s by Dr. Richard Riley, who is serving as an advisor for the current project. Until now, however, no analysis has attempted to determine whether this experimental knowledge can be put to practical use in real-world settings.

The current collaborative project will study the effectiveness of ultraviolet lamps in controlling TB in homeless shelters, where crowding and poor ventilation typically contribute to the spread of the disease. In the project, carefully designed UV fixtures, engineered in consultation with selected manufacturers, are placed at ceiling height. UV rays are transmitted horizontally in the upper part of the room, and the microscopic organisms, lighter than air, are lifted into the killing zone by convection currents in the building. The fixtures are designed with special louvers that keep the UV waves near the ceiling, eliminating virtually all exposure to people in the room.

Throughout the project, researchers will pay close attention to safety factors, strictly adhering to federal guidelines for human protection. The light being used is UV-C, a short-wave ultraviolet light that does not penetrate the skin or the cornea and therefore is not responsible for skin cancers or cataracts, as are the longer-wave UV-A and UV-B, which reach the earth from the sun.

With an overall TB rate 5 times the national average and a TB rate 75 times the national average among its homeless, New York City could benefit significantly from the technology. The specially designed lamps have already been installed at the Open Door drop-in center at 402 West 41st Street. Installations of UV systems in two homeless shelters in Birmingham, Alabama, will follow. Other possible U.S. sites are Atlanta, Chicago, Los Angeles, Miami, New Orleans, and San Diego. Locations in Europe and South Africa are also being considered.

If the study proves that UV lamps are effective in controlling TB and other airborne diseases, such as measles and influenza, it could pave the way for the technique to be applied in many other settings where the risk of TB is known. These include hospitals, schools, day care centers, transportation systems, auditoriums, jails, and prisons.

■ *For more information, contact Rande Wilson, (800) 424-3774.*

Researchers Probe Denver's Brown Cloud

Situated in a large, shallow valley and home to some two million people, Denver is subject to accumulations of airborne particulate matter and other emissions from multiple point and area sources under various types of meteorological conditions. Elevated fine-particle concentrations contribute to the brown cloud that sometimes hangs over the six-county metropolitan area.

Despite decades of research, emissions control, and substantial improvements in overall air quality, the brown cloud remains a persistent and complex problem for the Denver region. And experts still do not fully understand the sources and atmospheric conditions that contribute to the problem. In response, Colorado's governor authorized the Northern Front Range Air Quality Study (NFRAQS). This independent, peer-reviewed scientific study—the most comprehensive urban air pollution study ever conducted in the Intermountain West—is being collaboratively funded by several private and public organizations. Managed by Colorado State University and drawing on the expertise of EPRI, Public Service Company of Colorado, and other organizations skilled at investigating air quality, the study aims to close the knowledge gap so that state officials can assess current methods of air quality control and determine the best strategies for mitigating the problem in the future.

Through NFRAQS, researchers have gathered data on emissions, meteorology, and particulate matter through direct field measurements over the last two winters and in the summer of 1996. These data will be analyzed to determine the composition of atmospheric particles and to identify and quantify the relative contributions of various sources—including vehicles, wood burning, industries, and restaurant operations—for several kinds of meteorological episodes that enable accumulation. Specific objectives include determining the sources of such emissions as sulfate, nitrate, sulfur dioxide, carbon monoxide, nitrogen oxides, ammonia, and semivolatile organic compounds.

The project team will apportion carbonaceous and noncarbonaceous materials in atmospheric particles to specific source categories—information that should help clarify the extent to which various sources contribute to poor air quality. Researchers will also study a category of particulate matter called PM10—particles that are 10 micrometers or less in diameter and that reduce visibility and reach the lungs via inhalation. The researchers will determine what fraction of particulate matter PM10 particles constitute and will apportion this fraction to several source categories.

Data analysis will continue for much of 1997. A final report is expected to be released next year.

■ *For more information, contact Peter K. Mueller, (415) 855-2586.*

COURTESY COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

Denver's brown cloud

EPRI Building a Low-Cost Advanced Meter

Sophisticated sensor technology and a modular design will help drive down the cost of an advanced residential meter now under development at EPRI. Known as the

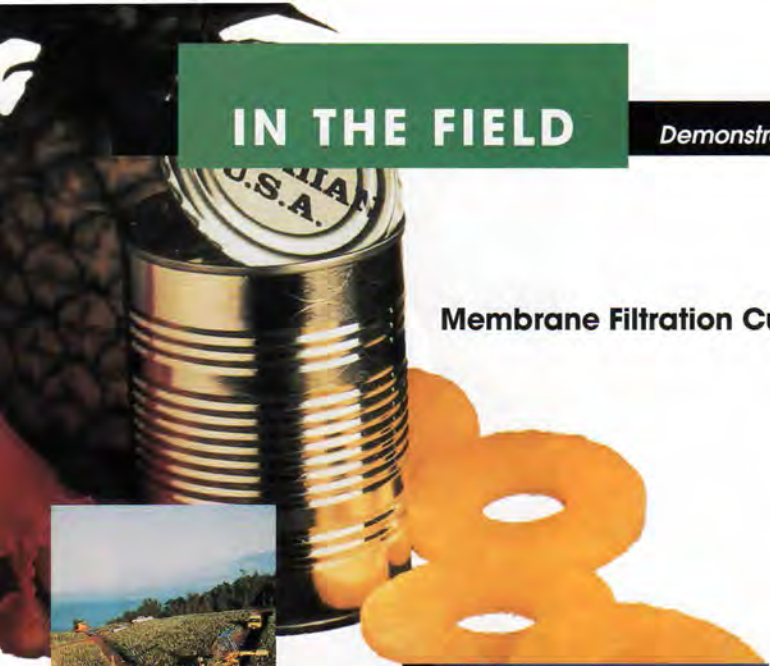
SE-240 meter

SE-240, this low-cost meter is being designed to work with add-on modules that will provide a choice of advanced capabilities, from disaggregated billing to security services.

"Other vendors have tried to put way too much functionality into the residential meter—functionality it doesn't need," says Dave Richardson, EPRI's manager for the project. "We're moving a lot of that functionality into the modules." Nonintrusive appliance load monitoring, outage location, real-time pricing, remote diagnostics, and power quality service are just some of the potential module capabilities. The meter is based on an open architecture, which will allow modules designed by any vendor to be plugged in and will help bring competition into the market.

While currently available electronic residential meters cost \$100–\$150 per unit, EPRI aims to price the SE-240 at \$30 per unit. At this time, researchers have developed a virtual prototype, which does not include the advanced sensor technology. That technology should be ready for implementation by the end of the year, when EPRI plans to release a proof-of-concept prototype. During the first quarter of next year, some 1000 meters from a preproduction run are expected to be released for sale to utilities.

■ *For more information, contact Dave Richardson, (415) 855-2331.*



IN THE FIELD

Demonstration and application of EPRI technology on utility systems

Membrane Filtration Cuts Costs at Maui Pineapple

TOP AND LEFT INSET PHOTOS COURTESY MAUI PINEAPPLE

Maui Pineapple Company, the sole producer of canned pineapple and pineapple juice in the United States, processes 175,000 tons of the fruit annually at its plant in Kahului. During processing, oil-fired evaporators remove water from a dilute juice solution to produce a concentrated sugar solution that is used in the canned fruit product. The company recently began looking for a cost-effective alternative to discharging process effluent into deep injection wells, but it couldn't pursue the preferred alternative—direct land application—because of the effluent's high pH levels. These levels, the result of ammonia discharge from the plant's ion-exchange units, would have required the use of large amounts of land.

Aware of EPRI R&D on membrane filtration for the recovery of food products and the treatment of process wastewater, Hawaiian Electric Company (HECO) and the Hawaii Department of Agriculture cosponsored a workshop that led to a six-week demonstration of a variety of membrane filtration technologies at Maui Pineapple. Cofunded by HECO and EPRI, the demonstration entailed tests on nine process streams at the Kahului plant, including effluent water, compressor condensate, and pineapple juice.

Several years earlier, Maui Pineapple had purchased and tested a pilot-scale reverse-osmosis membrane system, but the company lacked the resources to implement the technology at full scale. The HECO-EPRI tests, using EPRI's mobile demonstration unit, resulted in the reactivation of the reverse-osmosis system for ammonia recovery. By lowering the process effluent's pH, this reduced the number of acres required for direct land application of the effluent.

The trials also determined that membrane technology was a feasible alternative to replacing one of the plant's aging evaporators, at about one-quarter of the cost. The company found that if it installed a new reverse-osmosis unit to concentrate a mill juice stream, no new evaporator would be needed, avoiding $1.5 million in capital costs. Other applications of membrane filtration identified for Maui Pineapple in the project would reduce freshwater use, water discharge, and effluent loading.

Use of the mobile demonstration unit enabled Maui Pineapple to avoid making additional capital investments for pilot plant equipment. The HECO-EPRI project also spared the fruit processor over $37,000 in labor costs and $97,000 in other demonstration costs.

■ *For more information, contact Ammi Amarnath, (415) 855-2548, or Dee Graham, EPRI Food Technology Center, (510) 938-0928.*

PQPager Communicates With Marketing Executives

Ten utilities asked EPRI how they could get up-to-the-minute power quality data into the hands of their marketing executives. In response, EPRI developed the PQPager, an inexpensive power quality monitor that communicates directly with executives' pagers and has a built-in, voice-mail-like interface.

Less than 12 months after the PQPager was defined, 40 of the instruments were installed at substations and key customer service entrances in a successful field test involving Centerior Energy Corporation, Consolidated Edison Company of New York, Entergy Corporation, Northeast Utilities, OG&E Electric Services, Oglethorpe Power Corporation, Public Service Electric and Gas Company, Rochester Gas and Electric Corporation, San Diego Gas & Electric Company, and Western Resources.

The PQPager allows utility marketing executives to proactively respond to power quality events instead of waiting for an angry customer to call. With the device, the marketing representative knows almost instantly about sags, swells, and transients at key accounts. "The PQPager is more than just an instrument—it is a relationship tool," reports one of the project participants. "When we call a customer with specific information about a voltage sag that just occurred at their site, including how long the sag lasted and how low it went, the customer is much happier and views us more as a partner."

PQPager installed at a customer site

With a direct interface to paging service companies built in, the PQPager avoids the traditional bottleneck of communicating with a utility master station, although it has that capability. Avoiding such bottlenecks during systemwide events at utilities with hundreds of key customers was a critical product requirement.

Reaction from utilities participating in the field trials has been enthusiastic. Says Western Resources' Terrance Wilson, "The marketability of the EPRI PQPager is endless. Customers whom we involved in the beta tests are very impressed with the equipment. I look forward to the opportunity to offer it to more of our customers."

Interested utilities can try out the PQPager by dialing (408) 492-0784 from a touch-tone phone. The call will be answered by a PQPager at a California site set up by EPRI contractor BMI, who is commercializing the PQPager. Press 1 when instructed, then 789 when asked for a three-digit password. (Power for the demonstration site is supplied by Pacific Gas and Electric Company, but the site is not typical; many disturbances are caused intentionally by BMI engineers.)

EPRI has also developed a tabletop PQPager demonstration board for conferences, customer account meetings, and customer education. To inquire about scheduling the demonstration board, contact Marsha Grossman at EPRI, (415) 855-2899. An Underwriters Laboratories–listed, ISO 9000–certified commercial version of the PQPager is now available from BMI.

■ *For more information, contact Sid Bhatt at EPRI, (415) 855-8751, or Bob Zavadil at BMI, (408) 970-3700. On the Internet, see http://www.pqnet.electrotek.com/pqnet/main/PQPager.*

Hosts Sought for Trace Metal Removal Demonstration

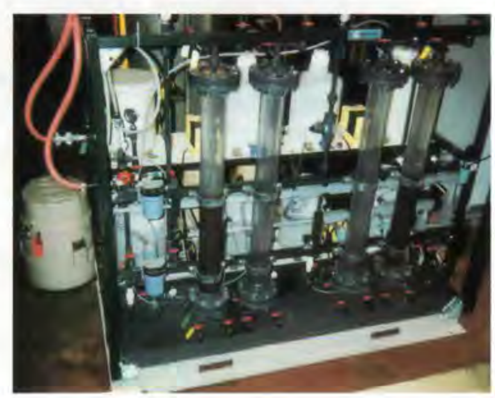
A water treatment process that uses iron-coated sand produces significantly smaller volumes of sludge than iron coprecipitation technology, currently used by some utilities to meet water-quality-based permit limits for heavy metals in wastewater. Developed by the University of Washington, the new process can effectively reduce metals to parts-per-billion levels, and because it produces less sludge, it promises substantially lower disposal costs than with conventional processes. Building on bench-scale studies that confirmed the viability of iron-coated sand filtration and identified its potential for lower treatment costs, EPRI is pursuing a series of pilot-scale field tests of the process at U.S. utility power plants.

Following a successful two-month demonstration last year at a Virginia power plant—where the process was used to remove copper, arsenic, and other trace metals from a wastewater effluent stream—additional host sites are being sought. As well as testing the overall chemical performance of the iron-coated sand process on actual power plant effluent streams, the EPRI program will determine system engineering and hardware requirements. It will also obtain physical and chemical scale-up data to enable more-accurate predictions of full-scale performance and costs and to facilitate comparisons with competing technologies. Results will be used to develop full-scale system design parameters.

Any operating power plant owned by an EPRI member can be a host site for a demonstration. Candidate trace metals include copper, arsenic, selenium, and others of specific interest to a host utility. If a site currently uses iron coprecipitation to treat a waste stream containing dissolved heavy metals, the EPRI project could include a comparison of its performance with iron-coated sand filtration. Each pilot plant test program is slated to last two to four months.

Benefits to host utilities will vary by site. On the basis of bench-scale data, EPRI estimates that the iron-coated sand process would have a levelized cost of $0.50 per 1000 gallons for a treatment plant with a capacity of 2000 gallons per minute (sufficient to handle a typical fossil power plant wastewater effluent flow). This compares with $1 per 1000 gallons for conventional iron coprecipitation. Sludge disposal costs for such an iron-coated sand filtration unit are projected to be $6000 a year, compared with $27,000 a year for an equivalent-capacity iron coprecipitation system.

■ *Interested member utilities should contact Paul Chu in EPRI's Environmental Control Business Area, (415) 855-2812.*



Iron-coated sand process test unit

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

CUSTOMER SYSTEMS

CLASSIFY-Profiles, Vol. 5: Designing Next-Generation Residential Energy Services

TR-104567-V5 Final Report (WO4954-3)
Contractors: National Analysts, Inc.; Hagler Bailly Consulting, Inc.
EPRI Project Manager: T. Henneberger
Fax ID: 40713

CLASSIFY-Applications, Vol. 2: How to Select and Use Customer Segmentation Systems That Work

TR-104568-V2 Final Report (WO4845-5)
Contractor: Hagler Bailly Consulting, Inc.
EPRI Project Manager: T. Henneberger
Fax ID: 40584

Guide to New Product and Service Development for the Emerging Market Environment

TR-107015 Final Report (WO4940)
Contractor: Barakat & Chamberlin, Inc.
EPRI Project Manager: P. Meagher
Fax ID: 40016

Strategic Evaluation of New Service Ventures

TR-107216 Final Report (WO4953-2)
Contractor: Putnam, Hayes & Bartlett, Inc.
EPRI Project Manager: T. Henneberger
Fax ID: 40472

Full Menu Restaurant Computer Simulations: Southern New Jersey

TR-107282-V1 Final Report (WO3544)
Contractor: Architectural Energy Corp.
EPRI Project Manager: K. Johnson
Fax ID: 40599

Full Menu Restaurant Computer Simulations: Savannah, Georgia

TR-107282-V2 Final Report (WO3544)
Contractor: Architectural Energy Corp.
EPRI Project Manager: K. Johnson
Fax ID: 40601

Full Menu Restaurant Computer Simulations: Atlanta, Georgia

TR-107282-V3 Final Report (WO3544)
Contractor: Architectural Energy Corp.
EPRI Project Manager: K. Johnson
Fax ID: 40617

Proceedings: EPRI Workshop on New Direction in Electricity Pricing

TR-107551 Final Report (WO2343)
Contractor: Barakat & Chamberlin, Inc.
EPRI Project Manager: P. Meagher
Fax ID: 40964

Marketing Strategies for Horizontal Axis Washers

TR-107612 Final Report (WO4953-3)
Contractor: Dove Associates, Inc.
EPRI Project Managers: R. Gillman, J. Kesselring
Fax ID: 41045

Market Research: Planning and Striking an Appropriate Balance for Business Results

TR-107684 Final Report (WO4TS2939)
Contractor: Dove Associates, Inc.
EPRI Project Manager: R. Gillman
Fax ID: 41198

Canadian Provincial and Territorial Vertical Borehole Grouting Regulations

TR-107709 Final Report (WO3881-1)
Contractor: Center for Applied Thermodynamic Studies, University of Idaho
EPRI Project Manager: C. Hiller
Fax ID: 41244

ENVIRONMENT

Studies of Residential Transients and Wire Configuration Codes

TR-105984 Final Report (WO3349-1)
Contractor: Enertech Consultants
EPRI Project Manager: R. Kavet
Fax ID: 25086

Childhood Cancer Risk, Wire Codes, and Residential Environment and Lifestyle Factors

TR-106376 Final Report (WO2964-22)
Contractor: Radian International LLC
EPRI Project Managers: K. Ebi, L. Kheifets
Fax ID: 25796

Insulating Oil Characteristics, Vols. 1 and 2

TR-106898-V1–V2 Final Report (WO4168, WO9087)
Contractors: CH2M Hill; META Environmental, Inc.; Pinnacle GeoSciences; Tetra Tech, Inc.
EPRI Project Manager: I. Murarka
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MOSES-MP Version 1.0: An IBM PC Code for the Evaluation of Mineral Oil Spills (User's Guide)

TR-106899 Final Report (WO4132)
Contractors: Tetra Tech, Inc.; University of Michigan
EPRI Project Manager: I. Murarka
Fax ID: 26649

MANAGES™ Version 2.0: Groundwater Data Management Software for Windows™ (User's Guide)

TR-106900 Final Report (WO9125, WO9020, WO4193)
Contractors: Tetra Tech, Inc.; Southern Company Services, Inc.; Science & Technology Management, Inc.
EPRI Project Manager: I. Murarka
Fax ID: 26650

LAYERS User's Guide: A Multilayer Magnetic Field Shielding Calculation Program

CM-107133 Final Report (WO3959-3)
Contractor: Electric Research & Management, Inc.
EPRI Project Manager: R. Takemoto-Hambleton
Fax ID: 40302

Implementation Manual for the Water-Effect Ratio (WER)

TR-107144 Final Report (WO2377-10)
Contractor: EA Engineering, Science, and Technology, Inc.
EPRI Project Manager: J. Mattice
Fax ID: 40315

The Timing of NO_x Emissions and Emission Trading in the Ozone Transport Region

TR-107186 Final Report (WO3835-2)
Contractor: National Economic Research Associates, Inc.
EPRI Project Manager: G. Hester
Fax ID: 40414

Managing Magnetic Fields: Insights From Decision Analysis

TR-107187 Final Report (WO2560-3)
Contractor: University of Southern California
EPRI Project Manager: G. Hester
Fax ID:40416

Cellular Responses to Low-Frequency Electromagnetic Fields: Resonant Effects on Calcium Binding to Calcium-Binding Proteins

TR-107236 Final Report (WO8911-16, WO2965-29, WO4308-4)
Contractor: University of Utah
EPRI Project Manager: C. Rafferty
Fax ID: 40513

Static Magnetic Field Perturbations and Pineal Melatonin Production

TR-107238 Final Report (WO8021-7)
Contractor: Department of Cellular and Structural Biology, University of Texas Health Science Center
EPRI Project Manager: R. Kavet
Fax ID: 40522

Mercury in the Environment: A Research Update

TR-107695 Final Report (WO3081, WO3508, WO3297)
EPRI Project Managers: L. Levin, D. Porcella
Fax ID: 41224

GENERATION

Water Resource Management and Hydropower: Guidebook for Collaboration and Public Involvement

TR-104858 Final Report (WO3713)
Contractors: Kearns & West, Inc.; Resources for the Future
EPRI Project Manager: C. McGowin
Fax ID: 23292

Corrosion Fatigue Crack Initiation of Boiler Tubes: Effect of Phosphate in Boiler Water

TR-105568 Final Report (WO1890-10)
Contractor: Babcock & Wilcox Co.
EPRI Project Manager: B. Dooley
Fax ID: 24445

Gas-Fired Boiler and Turbine Air Toxics Summary Report

TR-105646 Final Report (WO3177-21)
Contractor: Failure Analysis Associates
EPRI Project Managers: P. Chu, B. Toole-O'Neil
Fax ID: 24553

Nickel Speciation Measurements at Oil-Fired Power Plants

TR-105647 Final Report (WO3177)
Contractors: Carnot; University of Louisville
EPRI Project Manager: P. Chu
Fax ID: 24555

Proceedings: EPRI/DOE International Conference on Managing Hazardous and Particulate Air Pollutants

TR-105749 Proceedings (WO1213)
EPRI Project Manager: B. Toole-O'Neil
Fax ID: 24699

Advanced Gas Turbine Guidelines: Performance Retention for GE 7F Unit in Peaking Operation (Durability Surveillance at PEPCO's Station H)

TR-105856 Final Report (WO3125-2)
Contractor: Fluor Daniel, Inc.
EPRI Project Managers: W. Piulle, G. Quentin
Fax ID: 24869

Improved Gas Turbines for LBTU Syngas Fuel Operation

TR-105955 Final Report (WO2620-1)
Contractor: General Electric Co.
EPRI Project Manager: A. Cohn
Fax ID: 25043

Full-Scale F Technology Combustor Testing of Simulated Coal Gas

TR-105956 Final Report (WO2620-1)
Contractor: General Electric Co.
EPRI Project Manager: A. Cohn
Fax ID: 25045

Retrofitting Power Plants to Provide District Heating and Cooling

TR-106027 Final Report (WO2818-10)
Contractor: Joseph Technology Corp., Inc.
EPRI Project Manager: E. Petrill
Fax ID: 25167

Site-Specific Assessment Evaluating the Use of Modular Gas Turbines to Defer T&D Investments

TR-106037 Final Report (WO1677)
Contractor: Daniel, Mann, Johnson & Mendenhall
EPRI Project Manager: D. Rastler
Fax ID: 25183

Alternative Minimum Levels for Utility Aqueous Discharges: Chemical Analytical Measurement Guide for National Pollutant Discharge Elimination System (NPDES) Permits

TR-106220 Final Report (WO1851)
Contractor: TRW Inc.
EPRI Project Manager: B. Nott
Fax ID: 25496

Advanced Gas Turbine Guidelines: Performance Retention for GE 7FA Unit in Baseload Operation (Durability Surveillance at Florida Power & Light Co.'s Martin Station)

TR-106330 Final Report (WO3125-2)
Contractor: Energy & Environmental Research Center
EPRI Project Managers: W. Piulle, G. Quentin
Fax ID: 25703

Cycle Chemistry Improvement Program

TR-106371 Final Report (WO2712-11)
Contractors: General Physics Corp.; Sheppard T. Powell Associates; Jonas, Inc.
EPRI Project Manager: B. Dooley
Fax ID: 25788

Pilot Application of Streamlined Reliability-Centered Maintenance at TU Electric's Fossil Power Plants

TR-106503 Final Report (WO3151-1, WO3854-1)
Contractors: United Energy Services Corp.; TU Electric
EPRI Project Manager: R. Pflasterer
Fax ID: 25999

In-Situ Solidification/Stabilization of Arsenic-Contaminated Soils

TR-106700 Final Report (WO3006-1)
Contractor: Southern Company Services, Inc.
EPRI Project Manager: M. McLearn
Fax ID: 26332

Assessment of Impacts of NO_x Reduction Technologies on Coal Ash Use, Vol. 1: North American Perspective

TR-106747-V1 Final Report (WO3176-17)
Contractor: Radian International LLC
EPRI Project Manager: D. Golden
Fax ID: 26406

Roxboro Integrated Automation Project

TR-106803 Final Report (WO3487-12)
Contractor: EPRI Monitoring & Diagnostic Center
EPRI Project Manager: R. Colsher
Fax ID: 26495

Distributed Generation Workstation User's Manual

TR-106914 Final Report (WO4194-1)
Contractor: SEPRIL Services, LLC
EPRI Project Manager: D. Herman
Fax ID: 40856

Mercury and Other Trace Metals in Coal

TR-106950 Final Report (WO1213)
Contractors: RMB Consulting & Research; Frontier Geosciences, Inc.
EPRI Project Managers: P. Chu, D. Porcella
Fax ID: 39924

Trace Substance Emissions From a Coal-Fired Gasification Plant: Summary Report

TR-106964 Final Report (WO3177)
Contractor: Radian International LLC
EPRI Project Managers: P. Chu, M. Epstein
Fax ID: 39941

Evaluation of Cascaded Humidified Advanced Turbine (CHAT) Power Plant Options for TVA

TR-106990 Final Report (WO3816-2)
Contractor: Energy Storage and Power Consultants, Inc.
EPRI Project Manager: A. Cohn
Fax ID: 39979

Fluid Placement of Fixated Scrubber Sludge in Abandoned Deep Mines to Abate Surface Subsidence and Reduce Acid Mine Drainage

TR-107053 Final Report (WO9010-1, -2)
Contractors: Radian Corp.; Conversion Systems, Inc.
EPRI Project Manager: D. Golden
Fax ID: 40137

State-of-the-Art Assessment of Polymer Electrolyte Membrane Fuel Cells for Distributed Power Applications

TR-107064 Interim Report (WO4327)
EPRI Project Manager: D. Rastler
Fax ID: 40157

Santa Clara 2-MW Fuel Cell Demonstration Power Plant: Interim Acceptance Test Report

TR-107076 Interim Report (WO3377, WO3517)
Contractor: Westinghouse Electric Corp.
EPRI Project Managers: T. O'Shea, D. Rastler
Fax ID: 40182

A State-of-the-Art Review of Flue Gas Mercury Speciation Methods

TR-107080 Final Report (WO3471)
Contractor: Energy & Environmental Research Center
EPRI Project Manager: B. Nott
Fax ID: 40188

Zebra Mussel Control Using Periodic Clam-Trol 2™ Treatments

TR-107084 Final Report (WO3894)
Contractor: Illinois Power Co.
EPRI Project Manager: J. Tsou
Fax ID: 40196

A Review of Coal Mine Methane Recovery for Electric Utilities

TR-107092 Final Report (WO0982)
Contractor: ICF Resources Inc.
EPRI Project Manager: R. Rhudy
Fax ID: 40216

Advanced Planar Solid Oxide Fuel Cell Development, Phase 2: 25-kW Planar SOFC System Design

TR-107116 Final Report (WO8509-1)
Contractor: Ztek Corp.
EPRI Project Manager: R. Goldstein
Fax ID: 40270

Planar Solid Oxide Fuel Cell Stack Verification

TR-107117 Final Report (WO3608-1)
Contractor: Ztek Corp.
EPRI Project Manager: R. Goldstein
Fax ID: 40272

Comparative Evaluation of Control Strategies

TR-107118 Final Report (WO3891-2)
Contractor: PowerGen PLC
EPRI Project Manager: J. Weiss
Fax ID: 40274

Fabrication and Testing of IMHEX® Fuel Cell Stack

TR-107124 Final Report (WO3932-1)
Contractor: M-C Power Corp.
EPRI Project Manager: R. Goldstein
Fax ID: 40285

Field Evaluation of Westinghouse Tubular Solid Oxide Fuel Cell Technology

TR-107125 Final Report (WO3803)
EPRI Project Manager: J. O'Sullivan
Fax ID: 40287

Examination of Sabine 2 Hot Reheat Pipe Seam Weld Cracking

TR-107141 Final Report (WO2253-17)
Contractor: Failure Analysis Associates
EPRI Project Manager: V. Viswanathan
Fax ID: 40311

Fiber-Optic Fabry-Perot High-Temperature Strain Measurement System Feasibility Study

TR-107212 Final Report (WO3876-6)
Contractor: Mechanical Technology Inc.
EPRI Project Manager: J. Weiss
Fax ID: 40467

Railroad Consolidation and Market Power: Challenges to a Deregulating Electric Utility Industry

TR-107301 Final Report (WO4125-2)
Contractor: Fieldston Co., Inc.
EPRI Project Manager: J. Platt
Fax ID: 40667

EPRI Alternate Fuels Database

TR-107602 Final Report (WO4134-4)
Contractor: Foster Wheeler Environmental Corp.
EPRI Project Manager: E. Hughes
Fax ID: 41029

Preventing Leakage in Strand-to-Clip Connectors of Water-Cooled Generator Stator Windings

TR-107681 Final Report (WO2577-9)
Contractor: CC Technologies Laboratories, Inc.
EPRI Project Managers: B. Syrett, J. Stein, N. Hirota
Fax ID: 41193

Investigation on Lightweight High-Volume Fly Ash Concrete

TR-107685 Final Report (WO3176-12)
Contractor: Canada Centre for Mineral and Energy Technology
EPRI Project Manager: D. Golden
Fax ID: 41200

Heat Rate Improvement Source Book

TR-107733 Electronic Report (WO1681)
Contractor: EPRI Generation & Environmental Assistance Center
EPRI Project Manager: J. Tsou
Fax ID: 41282

NUCLEAR POWER

Guidelines for Electromagnetic Interference Testing in Power Plants: Revision 1

TR-102323-R1 Final Report (WO2409, WO4409)
Contractors: Public Service Electric and Gas Co.; CHAR Services; EPRI NDE Center
EPRI Project Manager: R. James
Fax ID: 41306

BWR Water Chemistry Guidelines: 1996 Revision

TR-103515-R1 Final Report (WO2493)
EPRI Project Manager: C. Wood
Fax ID: 41219

Development of a Condition Assessment Program for 4-kV, Environmentally Qualified Motors at CCNPP

TR-104736 Final Report (WO3343-1)
Contractors: Baltimore Gas and Electric Co.; Ogden Environmental and Energy Services Co., Inc.
EPRI Project Manager: J. Carey
Fax ID: 23074

PWR Molar Ratio Control Application Guidelines, Vol. 5: Westinghouse Evaluation of Effectiveness of Molar Ratio Control

TR-104811-V5 Final Report (WOS520-3)
EPRI Project Manager: P. Millett
Fax ID: 41044

EPRI PWR Fuel Cladding Corrosion (PFCC) Model, Vol. 2: Corrosion Theory and Rate Equation Development

TR-105387-V2 Final Report (WO1250-25)
Contractor: S. Levy Inc.
EPRI Project Manager: B. Cheng
Fax ID: 24205

Instrumentation and Control System Maintenance Planning Methodology, Vols. 1 and 2

TR-106029-V1–V2 Final Report (WO3373)
Contractors: ABB Combustion Engineering; Queue Systems, Inc.
EPRI Project Manager: D. Wilkinson
Fax ID: 25171

Dynamic Inspection Aptitude Test (DIAT) User's Guide

TR-106304 Final Report (WO3112-1)
Contractor: Anacapa Sciences, Inc.
EPRI Project Manager: L. Hanes
Fax ID: 25657

Post-Irradiation Evaluation of BWR Fuel From Hope Creek Reactor

TR-106348 Final Report (WO3609-1)
Contractor: GE Nuclear Energy
EPRI Project Manager: S. Yagnik
Fax ID: 25738

Preliminary Engineering Business Estimate (PLEBE)

TR-106421 Final Report (WO4202)
EPRI Project Managers: M. Campbell, L. Rubin
Fax ID: 25879

Cable Aging Management Program for D. C. Cook Nuclear Plant Units 1 and 2

TR-106687 Final Report (WO3698-2)
Contractors: American Electric Power Service Corp.; Ogden Environmental and Energy Services Co., Inc.
EPRI Project Manager: J. Carey
Fax ID: 26314

Risk-Informed Inservice Inspection Evaluation Procedure

TR-106706 Interim Report (WO3230)
Contractor: Yankee Atomic Electric Co.
EPRI Project Manager: S. Gosselin
Fax ID: 26341

Battery Performance Monitoring by Internal Ohmic Measurements: Emergency Lighting Unit Batteries

TR-106826 Final Report (WO4031-1)
Contractor: Edan Engineering Corp.
EPRI Project Managers: N. Hirota, W. Johnson
Fax ID: 26539

Valuation and Management of Nuclear Assets: Options Model and Case Studies

TR-106842 Final Report (WO4202)
Contractor: The Brattle Group
EPRI Project Managers: M. Campbell, R. Goldberg
Fax ID: 26566

Qualification of the AP/LOMI Decontamination Process for PWR Steam Generators

TR-107034 Final Report (WO4419-1)
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: H. Ocken
Fax ID: 40070

Chemistry of Defective Light Water Reactor Fuel

TR-107074 Final Report (WO3564-2)
Contractor: University of California, Berkeley
EPRI Project Manager: S. Yagnik
Fax ID: 40178

Alternative Method for Performing Regulatory Guide 1.154 Pressurized Thermal Shock Analysis

TR-107128 Interim Report (WO4175)
Contractors: Westinghouse Electric Corp.; Sartrex Corp.
EPRI Project Manager: R. Carter
Fax ID: 40293

Biosphere Modeling and Dose Assessment for Yucca Mountain

TR-107190 Final Report (WO3294-18)
Contractor: QuantiSci, Inc.
EPRI Project Manager: J. Kessler
Fax ID: 40422

Yucca Mountain Total System Performance Assessment, Phase 3

TR-107191 Final Report (WO3055-2)
Contractor: Risk Engineering, Inc.
EPRI Project Manager: J. Kessler
Fax ID: 40424

Steam Generator Blowdown Demineralizer: Waste Cost Reduction Process Options

TR-107199 Final Report (WO2414)
Contractor: CENTEC XXI
EPRI Project Manager: C. Hornibrook
Fax ID: 40438

User's Manual, WASTECOST: Wet Module, Version 1.0

TR-107200 Final Report (WO2414)
Contractors: Environmental Resources and Services; CENTEC XXI; NPI
EPRI Project Manager: C. Hornibrook
Fax ID: 40440

Operational Recommendations for Failed Fuel: An EPRI Perspective

TR-107217 Final Report (WO3564-3)
Contractor: ANATECH Corp.
EPRI Project Manager: S. Yagnik
Fax ID: 40474

Primary Water Chemistry, Fuel Rod Corrosion, and Crud Deposition in PWRs: A Comparison of European and U.S. Plant Performance

TR-107255 Final Report (WO3771-3)
Contractor: Aquarius Services Corp.
EPRI Project Manager: B. Cheng
Fax ID: 40553

BWR Iron Control, Vol. 1: Deep Beds

TR-107297-V1 Final Report (WO2977-16)
Contractor: Finetech Inc.
EPRI Project Managers: P. Millett, P. Frattini
Fax ID: 40658

BWR Iron Control, Vol. 2: Filters

TR-107297-V2 Final Report (WO2977-16)
Contractor: Finetech Inc.
EPRI Project Managers: P. Millett, P. Frattini
Fax ID: 41215

Electrochemical Noise Monitoring of BWR Systems
TR-107310 Final Report (WO3468-7)
Contractor: GE Corporate Research & Development
EPRI Project Manager: R. Pathania
Fax ID: 40682

Evaluation of PWR Radiation Fields: 1991–1996
TR-107566 Interim Report (WO2758-8)
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: H. Ocken
Fax ID: 40985

Material Specification for the Use of Type 348 Stainless Steel in Thin-Section LWR Internal Components
TR-107628 Final Report (WOC103-12)
Contractor: Stone & Webster Engineering Corp.
EPRI Project Manager: L. Nelson
Fax ID: 41070

Evaluation of Alternate Filter Elements for Condensate Polishing Applications at Catawba Nuclear Station
TR-107648 Final Report (WO3388)
Contractors: JoDAN Technologies, Ltd.; Duke Power Co.
EPRI Project Manager: P. Millett
Fax ID: 41141

Influence of Irradiation and Stress/Strain on the Behavior of Structural Materials, Phase 2
TR-107669 Final Report (WOC103-11)
Contractor: Siemens AG
EPRI Project Manager: L. Nelson
Fax ID: 41170

Influence of Irradiation and Stress/Strain on the Behavior of Structural Materials, Phase 3
TR-107670 Final Report (WOC103-11)
Contractor: Siemens AG
EPRI Project Manager: L. Nelson
Fax ID: 41172

Preventing Leakage in Strand-to-Clip Connectors of Water-Cooled Generator Stator Windings
TR-107681 (see listing under Generation)

POWER DELIVERY

Valuation and Management of Nuclear Assets: Options Model and Case Studies
TR-106842 (see listing under Nuclear Power)

Development of Conductor Deicing Systems
TR-107000 Final Report (WO4555)
Contractor: Springborn Laboratories, Inc.
EPRI Project Manager: R. Samm
Fax ID: 39993

Proceedings: The Future of Power Delivery, 1996 Conference
TR-107089 Final Report (WO4158-1)
EPRI Project Manager: A. Edris
Fax ID: 40206

Retail Service Design in Evolving Competitive Electricity Markets
TR-107546 Final Report (WO8501-1)
Contractor: Putnam, Hayes & Bartlett, Inc.
EPRI Project Manager: A. Vojdani
Fax ID: 40956

Transmission Dispatch and Congestion Management System (TDCMS)
TR-107571 Final Report (WO8510-2)
Contractor: Shir Power Engineering Consultants
EPRI Project Manager: A. Vojdani
Fax ID: 40992

Generating-Plant Investment and Retirement Decisions
TR-107635 Final Report (WO7004-2)
Contractor: The Northbridge Group
EPRI Project Manager: R. Goldberg
Fax ID: 41123

Development and Integration of CRAFT in Distributed Energy Management System Environment
TR-107706 Final Report (WO3708-1, -5, -6)
Contractor: University of Washington
EPRI Project Manager: D. Sobajic
Fax ID: 41240

Interconnected Power System Dynamics Tutorial: Second Edition
TR-107726 Final Report (WO1915-16)
Contractors: KEMA-ECC, Inc.; Operations Training Solutions
EPRI Project Manager: D. Sobajic
Fax ID: 41273

Nonlinear Power System Behavior Using Normal Forms
TR-107798 Final Report (WO8050-5)
Contractor: Iowa State University
EPRI Project Manager: D. Sobajic
Fax ID: 41427

UCA Advanced Broadband Communications Project
TR-107810 Final Report (WO3969-1)
Contractors: Houston Lighting & Power Co.; AT&T Network Systems
EPRI Project Manager: J. Melcher
Fax ID: 41443

STRATEGIC R&D

Application of Taxonomy Theory, Vol. 2
TR-105492-V2 Final Report (WO8050)
Contractor: Washington State University
EPRI Project Manager: D. Sobajic
Fax ID: 40495

In-Service Durability of Geomembranes
TR-106831 Final Report (WO8019-11)
Contractor: Southwest Research Institute
EPRI Project Manager: D. Golden
Fax ID: 26550

Advanced Planar Solid Oxide Fuel Cell Development, Phase 2: 25-kW Planar SOFC System Design
TR-107116 (see listing under Generation)

The Status of CVD Diamond for Power Electronic Applications
TR-107122 Final Report (WO8069-1)
Contractor: KOBE Steel USA, Inc.
EPRI Project Manager: A. Katz
Fax ID: 40280

New Computer Software

Orders for EPRI-developed software should be directed to the Electric Power Software Center, 11025 North Torrey Pines Road, La Jolla, California 92037; (800) 763-3772.

ASAPP2: Accounting Software Application for Pollution Prevention
Version 1.01 (PC-DOS)
Contractor: Radian International LLC
Business Area: Environmental Control
EPRI Project Manager: Mary McLearn

CAT Workstation™: Clean Air Technology Workstation
Version 3.0 (PC-Windows)
Contractors: Sargent & Lundy; InStep Software
Business Area: Environmental Control
EPRI Project Manager: Richard Rhudy

DGWorkstation: Distributed Generation Workstation
Version 1.1 (PC-Windows)
Contractor: SEPRIL Services
Business Groups: Customer Systems; Generation; Power Delivery
EPRI Project Manager: Doug Herman

Electricity Book
Version 0.65 (Windows)
Contractor: The Brattle Group
Business Area: Power Markets & Resource Management
EPRI Project Manager: Richard Goldberg

ESCA: Electric Service Capacity Analyst
Version 1.5 (PC-DOS)
Contractor: Architectural Energy Corp.
Business Area: Commercial Technologies & Services
EPRI Project Manager: Karl Johnson

GTOP™: Gas Turbine Overhaul Plan for GE MS7001 Simple-Cycle Units
Version 1 (PC-DOS)
Contractor: Combustion Turbine Technologies Division of J. A. Jones Applied Research Co.
Business Area: New Generation
EPRI Project Manager: Robert Frischmuth

PREP4: A Power Reactor Vessel Materials Database Program
Version 1.0 (PC-DOS)
Contractor: ATI Consulting
Business Area: Nuclear Power
EPRI Project Manager: Stan Rosinski

ProfitManager
Version 3.5 (PC-Windows)
Contractor: EPS Solutions
Business Area: Retail Market Tools & Services
EPRI Project Manager: Paul Meagher

SDWorkstation: Substation Design Workstation
Version 1.0 (PC-Windows)
Contractor: Power Technologies, Inc.
Business Area: Transmission & Substations
EPRI Project Manager: Ben Damsky

EPRI Events

JULY

8–9
Detection and Control of Flow-Accelerated Corrosion in Fossil Plants
Philadelphia, Pennsylvania
Contact: Melita Guellert, (415) 855-2010

10–11
7th Annual NDE Center Subscribers Meeting
Charleston, South Carolina
Contact: Susan Otto, (704) 547-6072

14–16
Power Quality Technical Training
Knoxville, Tennessee
Contact: Lisa Nederhoff, (423) 570-8014

14–16
6th EPRI Valve Technology Symposium
Portland, Maine
Contact: Susan Otto, (704) 547-6072

14–18
Steam Plant Operations for Utility Engineers
Castine, Maine
Contact: Ginny Commiciotto, (207) 326-2212

15–16
Understanding Transmission Reservation and Scheduling Processes
Cincinnati, Ohio
Contact: Denise Wesalainen, (415) 855-2259

15–17
Motor Rewind Seminar
Charleston, West Virginia
Contact: Denise Wesalainen, (415) 855-2259

15–18
EPRI Electricity Book Training and Users Meeting
New York, New York
Contact: Susan Marsland, (415) 855-2946

21–22
Understanding Transmission Reservation and Scheduling Processes
Denver, Colorado
Contact: Denise Wesalainen, (415) 855-2259

21–23
ABB (ITE) Low- and Medium-Voltage Circuit Breaker Users Group
Baltimore, Maryland
Contact: Linda Suddreth, (704) 547-6141

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

21–23
Value and Risk in Competitive Markets
Cincinnati, Ohio
Contact: Art Altman, (415) 855-8740

21–24
Infrared Thermography Users Group
Richland, Washington
Contact: Edie McFall, (800) 745-9982

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

23–25
PC Lite: Power Option Evaluator Training
St. Louis, Missouri
Contact: Art Altman, (415) 855-8740

28–August 1
Terry Turbine Workshop
Houston, Texas
Contact: Linda Suddreth, (704) 547-6141

29–31
Fluid-Film Bearing Diagnostics
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

29–August 1
5th EPRI Steam Turbine–Generator Workshop
Lake Buena Vista, Florida
Contact: Paul Sabourin, (704) 547-6155

AUGUST

5
Water and Energy Conference
Houston, Texas
Contact: Kim Schilling, (314) 935-8590

5–7
Acoustic Emission Monitoring of Reheat Piping
Eddystone, Pennsylvania
Contact: Jeanne Harris, (800) 745-9982

11–12
Nuclear Plant Performance Improvement Seminar
San Antonio, Texas
Contact: Bruce Lube, (704) 547-6080

11–14
Cooling Tower Conference
St. Petersburg, Florida
Contact: Susan Bisetti, (415) 855-7919

12–14
Plant Performance Enhancement Program
San Antonio, Texas
Contact: Bruce Lube, (704) 547-6080

12–15
Generator Monitoring and Diagnostics
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

12–15
Motor Monitoring and Diagnostics
Long Beach, California
Contact: Jeanne Harris, (800) 745-9982

18–22
Steam Plant Operations for Utility Engineers
Castine, Maine
Contact: Ginny Commiciotto, (207) 326-2212

18–22
Water-Heating Week
Lake Tahoe, Nevada
Contact: Denise Wesalainen, (415) 855-2259

23–25
Power Plant Pumps Short Course
Eddystone, Pennsylvania
Contact: Jeanne Harris, (800) 745-9982

25–27
1997 EPRIweb Conference
Washington, D.C.
Contact: Michele Samoulides, (415) 855-2127

25–27
Transmission Line Cascading Failure Risk Assessment
Columbus, Ohio
Contact: Susan Marsland, (415) 855-2946

25–29
SO_2/NO_x/Particulates/CEM Symposium
Washington, D.C.
Contact: Lori Adams, (415) 855-8763

26–27
Reserve Services Workshop
Morristown, New Jersey
Contact: Vic Niemeyer, (415) 855-2744

27
Workshop on Business Practices for Environmental Excellence
Denver, Colorado
Contact: Mary McLearn, (415) 855-2487

SEPTEMBER

8–10
Electric Motor Predictive Maintenance
Chesterfield, Missouri
Contact: Melita Guellert, (415) 855-2010

8–10
Transmission Structure Coatings Workshop
Nashville, Tennessee
Contact: Kathleen Lyons, (415) 855-2656

9–12
Basic Vibration Testing and Analysis
Eddystone, Pennsylvania
Contact: Jeanne Harris, (800) 745-9982

10–12
Value and Risk in Competitive Markets
Denver, Colorado
Contact: Art Altman, (415) 855-8740

15–17
Lubrication and Bearing Workshop
Albuquerque, New Mexico
Contact: Linda Suddreth, (704) 547-6141

15–17
1997 Condensate Polishing Workshop
New Orleans, Louisiana
Contact: Barbara James, (707) 823-5237

16–18
Underground Transmission Technical Review
Philadelphia, Pennsylvania
Contact: Kathleen Lyons, (415) 855-2656

16–19
Transformer Performance, Monitoring, and Diagnostics
Long Beach, California
Contact: John Niemkiewicz, (800) 745-9982

18–19
OASIS Conference
Burlingame, California
Contact: Denise Wesalainen, (415) 855-2259

22–23
Industrial Minerals and Cement Workshop
St. Louis, Missouri
Contact: John Kollar, (412) 268-3435

22–26
Infrared Thermography: Level 1
Long Beach, California
Contact: Jeanne Harris, (800) 745-9982

23–25
Joint EPRI/GRI Seminar on the Management of Manufactured Gas Plant Sites
Washington, D.C.
Contact: Ishwar Murarka, (415) 855-2150

23–26
Price-Product Mix Analysis Workshop
Boston, Massachusetts
Contact: Rich Goldberg, (415) 855-2397

24–25
Lightning Protection Design Workstation Version 4.0 Workshop
Dallas, Texas
Contact: Vito Longo, (415) 855-8586

25–26
Operational Reactor Safety Engineering and Review Group
La Jolla, California
Contact: Susan Bisetti, (415) 855-7919

26
Rough Sets and Fuzzy Logic Tutorial and Workshop
Palo Alto, California
Contact: Martin Wildberger, (415) 855-1043

30–October 3
Steam Turbine Performance Monitoring, Diagnostics, and Improvement
San Antonio, Texas
Contact: Jeanne Harris, (800) 745-9982

OCTOBER

1
Water and Energy Conference
Charleston, South Carolina
Contact: Kim Shilling, (314) 935-8590

6–7
Workshop on New Product and Service Development
Washington, D.C.
Contact: Lynn Stone, (972) 556-6529

6–8
Gasification Technologies Conference
San Francisco, California
Contact: Michele Samoulides, (415) 855-2127

7–8
Motor Rewind Course
Wharton, New Jersey
Contact: Denise Wesalainen, (415) 855-2259

7–8
REEPS Software Training
San Diego, California
Contact: Paige Schaefer, (800) 398-0081

7–9
Infrared Thermography: Level 3
Long Beach, California
Contact: John Niemkiewicz, (800) 745-9982

8–10
Live Working 2000 Workshop
Lenox, Massachusetts
Contact: Kathleen Lyons, (415) 855-2656

8–10
Substation and Switchyard Predictive Maintenance
Eddystone, Pennsylvania
Contact: Jeanne Harris, (800) 745-9982

9–10
COMMEND Software Training
San Diego, California
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13–14
INFORM Software Training
San Diego, California
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14–17
Safety and Relief Valve Workshop
Huntsville, Alabama
Contact: Linda Suddreth, (704) 547-6141

16–17
EPRI Partnership for Industrial Competitiveness
Allentown, Pennsylvania
Contact: Bill Smith, (415) 855-2415

16–17
Strategic Asset Management: More Applications, New Results
New Orleans, Louisiana
Contact: Vic Niemeyer, (415) 855-2744

20–24
Infrared Thermography: Level 2
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

20–24
3d Annual Distributed Resources Conference
Baltimore, Maryland
Contact: Lori Adams, (415) 855-8763

22–23
MANAGES and MOSES-MP Software Training
Charlotte, North Carolina
Contact: Adda Quinn, (415) 855-2478

23–24
HELM Software Training
Dallas, Texas
Contact: Paige Schaefer, (800) 398-0081

26–30
1997 EPRI Performance Measurement Workshop
Denver, Colorado
Contact: Lynn Stone, (972) 556-6529

27–28
OASIS Conference
Danvers, Massachusetts
Contact: Denise Wesalainen, (415) 855-2259

27–28
Power Quality Marketing Workshop
Knoxville, Tennessee
Contact: Lisa Nederhoff, (423) 570-8014

27–29
NMAC Workshop on Stationary Battery Maintenance
Atlanta, Georgia
Contact: Linda Suddreth, (704) 547-6141

28–30
Achieving Success in Evolving Electricity Markets
Houston, Texas
Contact: Michele Samoulides, (415) 855-2127

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Power Quality Advanced Training
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3–5
Power Quality Interest Group
San Diego, California
Contact: Carrie Koeturius, (510) 525-1205

5–7
Fuel Supply Seminar
Chattanooga, Tennessee
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9–12
Electric Furnace Conference
Chicago, Illinois
Contact: Joe Goodwill, (412) 268-3435

10–11
Application and Development of Superconducting Cables
Columbia, South Carolina
Contact: Kathleen Lyons, (415) 855-2656

10–12
Decision Analysis for Utility Planning and Management
San Diego, California
Contact: Charlie Clark, (415) 855-2994

11–12
Forecasting in a Competitive Electricity Market
Arlington, Virginia
Contact: Lynn Stone, (972) 556-6529

11–13
Boiler Tube Failure
Nashville, Tennessee
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EPRI JOURNAL

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

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NONPROFIT ORGANIZATION
U.S. POSTAGE
PAID
PERMIT NUMBER 181
LIBERTY, MO 64068

May/June 1997

Printed on recycled paper
in the United States of America

EJ-108331