Rethinking Pricing

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ELECTRIC POWER RESEARCH INSTITUTE

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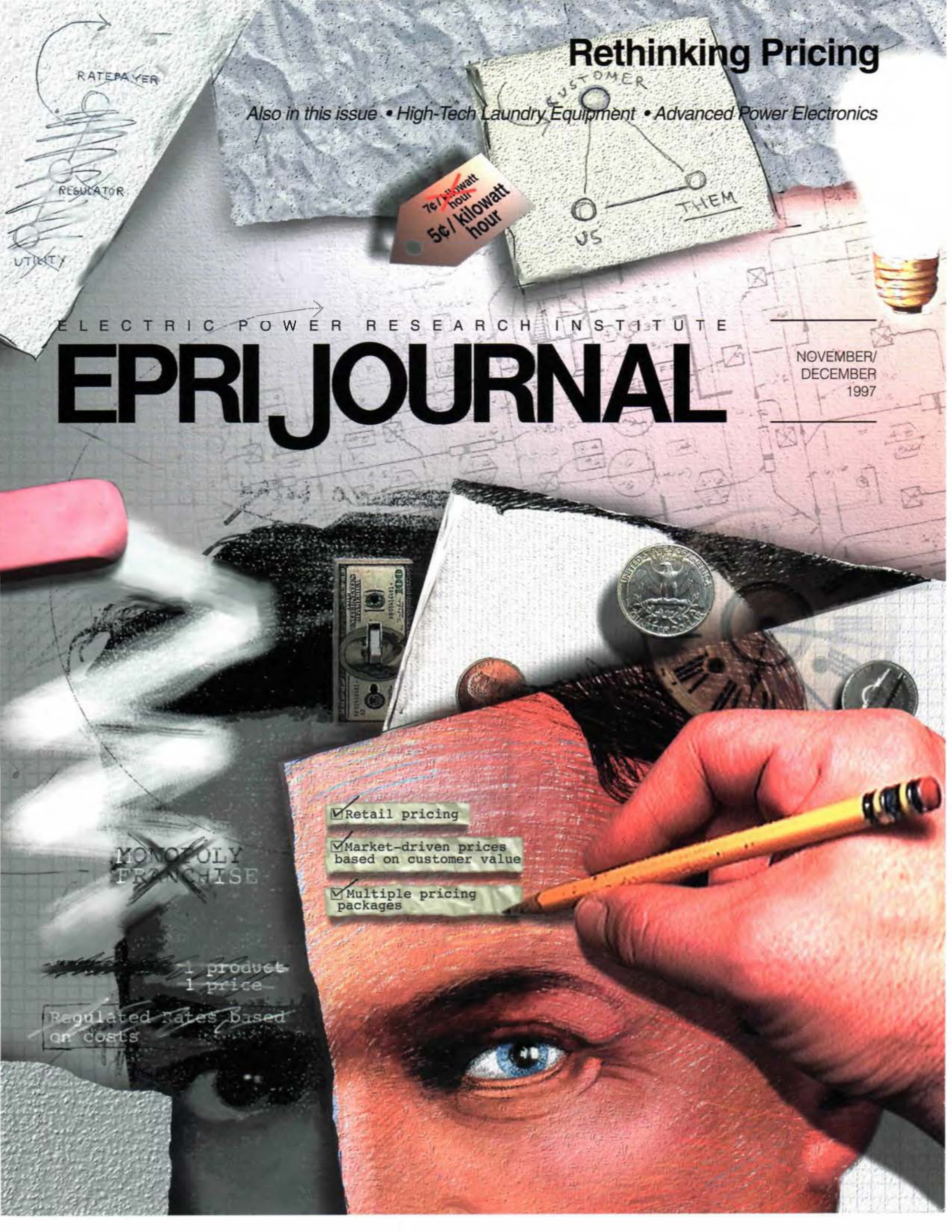

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Cover: Competing successfully in a deregulated market will require utilities to develop a new mind-set on pricing—one that not only offers customers a greater range of choice but also recognizes threats from rival suppliers. (Illustration by Steve Campbell)

EPRI JOURNAL

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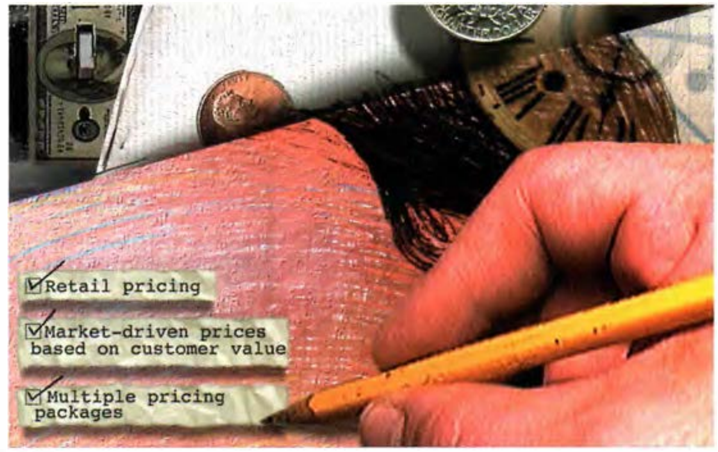

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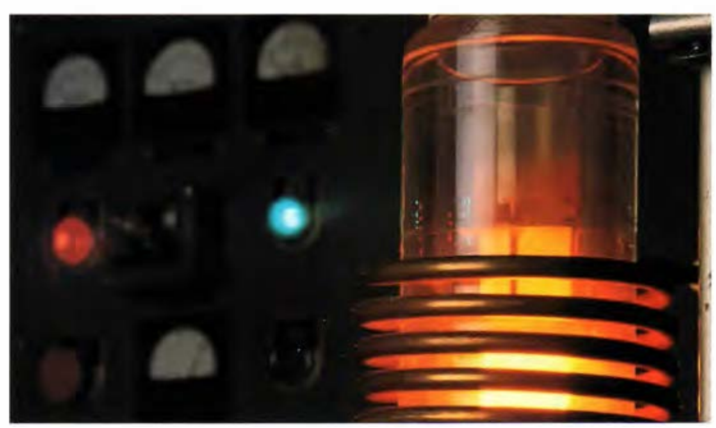

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PRODUCTS

EPRI-sponsored deliverables now available to utilities and their customers

Four EPRI-sponsored products won R&D 100 awards this year. The awards are presented by *R&D Magazine*, which assembles a panel of scientific experts for the annual competition. The experts select 100 new products they consider the year's most technologically significant. On the list for 1997 are PQ2000, the RTP Controller, and the Low-Dross Aluminum Melter (all featured here), as well as the Non-Intrusive Appliance Load-Monitoring System, featured in the Products department of the May/June 1997 *EPRI Journal*.

PQ2000

Voltage-related power disturbances cost U.S. businesses tens of billions of dollars in lost productivity each year, EPRI studies show. The PQ2000 power quality system—developed by AC Battery Corporation of Troy, Wisconsin, in conjunction with General Motors' Delphi Energy & Engine Management Systems division, Oglethorpe Power Corporation, and EPRI—has the potential to restore much of this lost productivity. Functioning like a conventional uninterruptible power supply, PQ2000 keeps computers and other sensitive electronic equipment operating smoothly during momentary voltage fluctuations. What sets PQ2000 apart are its highspeed response capability and a proprietary technology that extends battery life and eliminates many of the maintenance and reliability issues normally associated with stationary battery systems.

For more information, contact Ben Banerjee, (650) 855-7925. To order, call Bob Flemming at AC Battery Corporation, (414) 642-7416.

RON MAY

RTP Controller

A number of electric power companies now offer real-time pricing (RTP) rates to their large commercial and industrial customers. These rates, which vary according to the cost of producing electricity, can offer significant savings. In order to take advantage of RTP rates, however, customers need to adjust lighting, cooling, heating, and ventilation systems numerous times throughout the day. Since performing this task manually is not practical, EPRI and Honeywell, Inc., developed the RTP Controller to automate the process. A software module running in a Honeywell energy management system, the controller reduces energy costs without compromising the comfort, indoor air quality, or safety of customers' operations. The Marriott Marquis Hotel in New York City, which installed the controller in 1993, has saved over $1 million in power costs.

For more information, contact John Flood, (201) 697-6007. To order, contact your local Honeywell dealer.

Low-Dross Aluminum Melter

COURTESY PROCESS ENGINEERING DYNAMICS

Developed by EPRI in collaboration with Process Engineering Dynamics, this melter offers an energy-efficient and environmentally sound solution to one of the toughest challenges facing the aluminum-recycling industry—dross. An essentially solid by-product created when aluminum reacts with oxygen in the furnace of a secondary aluminum melter, dross can reduce melter production by as much as 10%. The Low-Dross Aluminum Melter uses argon gas to provide a stable, nonoxidizing atmosphere that reduces dross by more than 60%. The result is an increase in production of about $2 million annually for the average aluminum recycler. And that's not counting the $600,000 saved in hauling and landfill costs.
For more information, contact Bob Schmitt, (412) 268-6442. To order, call Frank Kemeny at Process Engineering Dynamics, (716) 774-1393.

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Fuel Market Reports

To help U.S. power producers plan for industry restructuring, EPRI and the Gas Research Institute are collaborating on a series of reports assessing the potential impacts on power generation, fuel use, business practices, and information needs. The first two reports in the series—*Impacts of Electric Industry Restructuring on Electric Generation and Fuel Markets: Analytical and Business Challenges* (TR-107614) and *Regional Impacts of Electric Utility Restructuring on Fuel Markets* (TR-107900, Vols. 1 and 2)—analyze generation and transmission circumstances across the country and describe the pace of restructuring in different regions. They include perspectives on changes in interregional power flows, effects on existing plants (e.g., utilization changes, upgrades, accelerated retirements), and the stimulus to gas generation.
For more information, contact Jeremy Platt, (650) 855-2628. To order, call the EPRI Distribution Center, (510) 934-4212.

Fish Passage Guidelines

By the year 2010, more than 20,000 MW of hydroelectric generating capacity will undergo relicensing by the Federal Energy Regulatory Commission. In many cases, applicants will have to conduct fish entrainment and/or survival studies for hydro turbines. To reduce the time and expense involved in meeting this requirement, EPRI developed *Guidelines for Hydro Turbine Fish Entrainment and Survival Studies* (TR-107299). This document offers, for the first time, standardized protocols for planning and conducting such studies and analyzing and reporting their results.
For more information, contact Chuck Sullivan, (650) 855-8948. To order, call the EPRI Distribution Center, (510) 934-4212.

SALMON PHOTO © 1997 PAUL McCORMICK/THE IMAGE BANK

Progress on the Wire Code Paradox

Since 1979, reports of a possible link between childhood cancer and magnetic fields from neighboring power lines have given the public cause for concern. Because making actual magnetic field measurements was impractical in early studies, researchers used wire codes—classifications of the size and proximity of power lines to homes—as surrogates for field strength. Studies conducted in Denver and Los Angeles reported associations between childhood cancer (leukemia) and the highest wire code levels, but associations between the disease and exposure estimates based on present-day magnetic field measurements in subjects' homes have been shown to be much weaker. This discrepancy has been called the wire code paradox and has generated considerable interest among scientists studying the possible health effects of electric and magnetic fields.

PHOTO © 1997 TIM BIEBER/THE IMAGE BANK

Contradictory conclusions have recently been published regarding the association between childhood cancer and wire codes. In 1996, the National Academy of Sciences reviewed the residential studies published to date and concluded that "wire codes are associated with childhood cancer, but the cause for the association is unknown." Further, the report's executive summary stated that "the current body of evidence does not show that exposure to [magnetic] fields presents a human-health hazard." In July 1997, Martha Linet and her colleagues reported no association between wire codes and childhood leukemia in the midwestern states they studied.

EPRI has been funding research on the wire code paradox, including investigations of magnetic fields, transients, and other factors. As part of this effort, researchers examined certain residential environment and lifestyle factors (RELs) to determine if the factors could be related to both wire codes and the occurrence of childhood cancer. The findings were presented in a 1996 EPRI report entitled *Childhood Cancer Risk, Wire Codes, and Residential Environment and Lifestyle Factors* (TR-106376). The researchers—Robert Pearson of Radian International LLC, Howard Wachtel of the University of Colorado, and Kristie Ebi of EPRI—used data from the 1988 childhood cancer study conducted by David Savitz and his colleagues in Denver, as well as data from public databases. Geographic information system, or GIS, software was used to map the data for residences of children with cancer and a control group of healthy children.

The researchers concluded that two distinct factors were associated both with the wire code designated VHCC (very high current configuration) and with increased cancer occurrence. Being a tenant rather than a home owner was the first factor, and the second was traffic density near the residence. Neither factor alone is a direct cause of cancer, but they may be markers for other risk factors or sets of factors. Regarding tenancy, it is not known why this is a factor, only that the research determined it was. Associations with traffic density appear to be much stronger and offer more opportunities for further investigation.

Post hoc analyses indicated that the unadjusted rate of cancer among children who lived close to the busiest streets (more than 20,000 vehicles per day) was eight to nine times greater than that among children who lived close to streets with the lowest traffic density. In comparison, the rate of cancer among children who lived in VHCC residences was about twice that among children who lived in residences with buried utility lines. According to EPRI project manager Kristie Ebi and the two other researchers, traffic density may be a marker for local air pollution, specifically volatile organic compounds and other emissions.

Although this additional research has shed new light on the controversial topic of childhood cancer, the wire code paradox remains. At least two questions need to be addressed: Are the data from the Denver study unique to that city, or can the findings be generalized; and are the factors of traffic density and tenancy versus home ownership new surrogates for the occurrence of childhood cancer?

Further research is being conducted to begin to answer these questions. One EPRI-funded study by Pearson, Wachtel, Ebi, and Bryan Langholz (a statistician at the University of Southern California) is examining the feasibility of applying the methods developed in the Denver study—including automatic wire coding and mapping of REL factors—to Los Angeles. In addition, the researchers are developing an efficient epidemiologic design to study the associations between the VHCC wire code, magnetic fields, other REL factors, and childhood leukemia. Another EPRI-funded study by Pearson, Wachtel, and Ebi is investigating the associations between childhood cancer, wire codes, and traffic density. A model for evaluating traffic density will be developed and tested. Much more work needs to be done, but the mystery surrounding a possible link between childhood cancer, wire codes, and RELs may soon be resolved.

■ *For more information, contact Kristie Ebi, (650) 855-2735.*

Monitoring Corrosion On-Line With Fiber Optics

Fiber-optic strain gages offer a novel way to measure the onset of intergranular attack (IGA) and the progression of stress corrosion cracking (SCC) on the outside surface of nuclear steam generator tubes at support plate crevices. An experimental on-line crack-monitoring system developed for EPRI by McDermott International Corporation's Babcock & Wilcox subsidiary uses light-emitting-diode sources and solid-state light detectors at each end of optical fibers to measure changes in strain in a tube. In laboratory tests, the fiber-optic gages proved more sensitive than standard foil strain gages in detecting strain changes caused by the onset of cracking.

Previous attempts to develop on-line devices for measuring localized IGA and SCC at high temperatures generally were thwarted either by the unreliability of signal transmission or by the degradation of the devices' materials by hot water. EPRI Strategic R&D sought to determine whether the use of a fiber-optic corrosion probe in a sidestream model boiler simulating support plate crevice regions could circumvent these problems and provide real-time data.

Strain gage installed on tube specimen

Researchers performed two tests with a combination of aluminum-buffered and polyamide-buffered fiber-optic strain gages. In the first test, two high-temperature, microbend fiber-optic strain gages and two resistive-foil strain gages were installed on the outside surface of an Alloy 600 tube specimen. The tube was then axially loaded to near yield. The change in strain output was recorded while part of the inside tube surface was exposed to a corrosive fluid at ambient temperature.

In the second test, four fiber-optic strain gages were installed on the outside surface of another Alloy 600 tube specimen. The tube was placed in an autoclave, where it was subjected to high temperatures and pressures for over 600 hours. Water with various concentrations of caustic sodium hydroxide was circulated through the tube, which was axially loaded.

The tests demonstrated that fiber-optic strain gages attached to the outside surface of a steam generator tube can successfully monitor tube wall stress, wall thinning, and wall strain to the point of failure due to IGA/SCC. Overall, the gages were able to detect 10–20 nanometers of stretch motion and to detect changes as small as about 1 microstrain.

Fiber-optic technology has many attractive features for the on-line monitoring of IGA/SCC in steam generator tubing, including extremely high sensitivity and immunity from electrical noise. Also, because optical fibers are more rugged and corrosion-resistant than electric conductors, the technology can be used at higher temperatures.

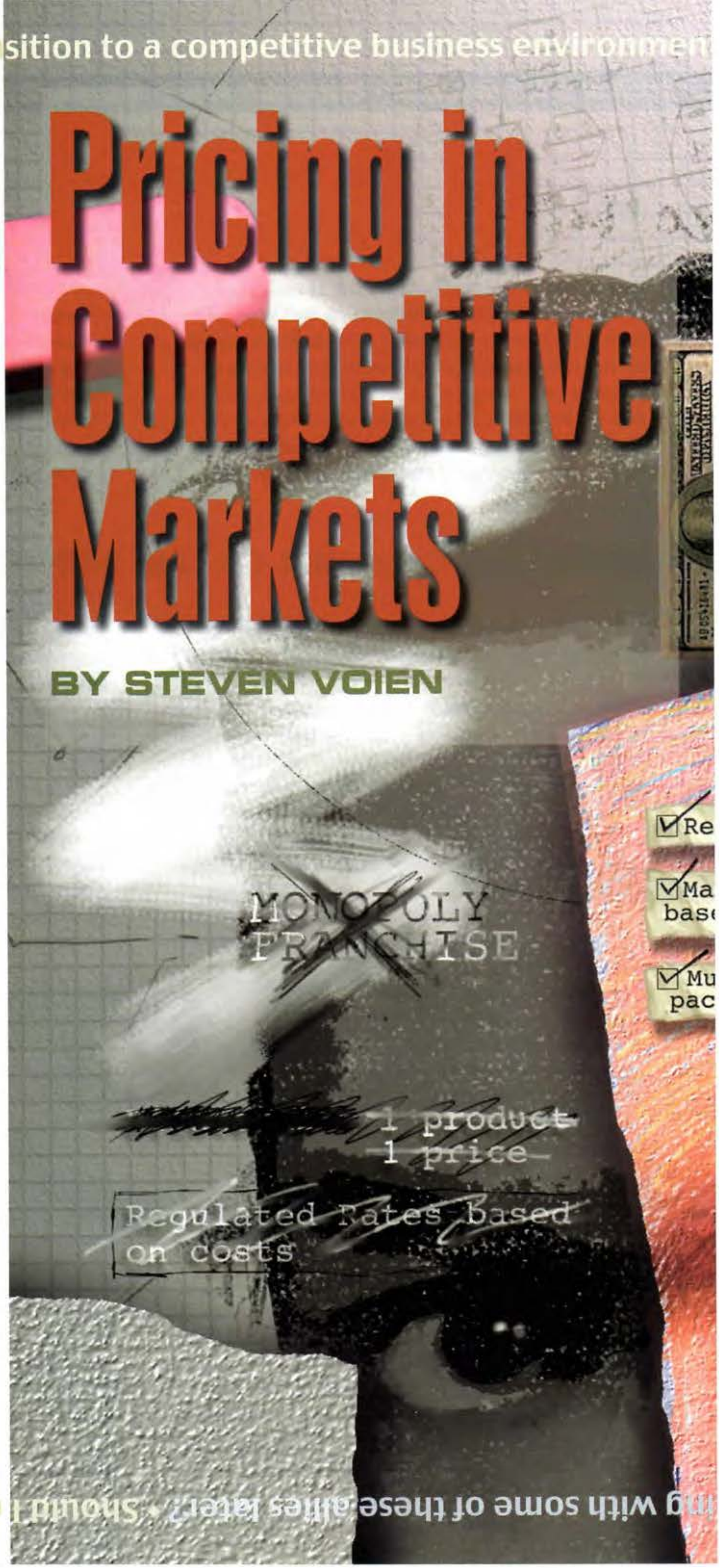
While materials issues continue to be the most significant development challenge, the use of such higher-temperature optical fibers as sapphire may extend the life of an on-line corrosion monitor. The laboratory test results suggested several design improvements that, in the next phase of R&D, could be incorporated into a prototype strain gage corrosion detector for field testing in a sidestream model boiler. A technical report (TR-104782) documenting the laboratory work is available from the EPRI Distribution Center, (510) 934-4212.

■ *For more information, contact Barry Syrett, (650) 855-2956.*

How should I manage the transition to a competitive business environment

Pricing in Competitive Markets

BY STEVEN VOIEN



THE STORY IN BRIEF

As incumbent electric utilities gear up to face a deregulated retail marketplace, many have focused their efforts on cutting costs—downsizing their operations and negotiating new contracts with power generators. These efforts, while necessary, won't be enough to create enduring competitive advantage. The greatest opportunity for farsighted managers to create real value for customers and stockholders falls squarely in the domain of retail pricing. A company must be able to move from regulated rates based on costs to market-driven prices based on customer value. This shift will require an improved capacity to gather customer—and competitor—information relevant to market-based pricing. It will also require the acquisition of new pricing tools and the ability to use those tools quickly to make and implement sales and marketing decisions. Finally, it will require a change in the conceptualization of the customer relationship, which is no longer a bilateral relationship between supplier and customer but a triangle that includes the competition.

functions? • What lessons can I learn from firms that have already made the transition? •

ing with some of these allies later? • Should I outsource certain noncritical

• Should I create unregulated affiliate companies? • How do I assess my core competency? • What skills and staff are transferable? • Should I form strategic alliances to enhance my core competency at minimum cost? • Will I end up compe

STEVE CAMPBELL

On January 1, 1998, California—the country's biggest electricity market ($21 billion) and the world's sixth largest economy—will make an overnight leap into the competitive unknown. The rules of the electric power game will change entirely, and incumbent utilities will suddenly have a good deal of company in what was once their exclusive preserve. Customer choice and customer value, rather than government regulators, will be the new determinants of price in the marketplace, as consumers—be they homeowners, small businesses, or large industrial or commercial users—wake up on January 1 to the knowledge that they can buy electricity from whomever they please.

Giant multinational oil firms like Shell Oil and Texaco, natural gas marketers like Enron, and small startup companies run by recent college graduates are well along in their preparations to enter the electricity market; many are already vying for customers through television spots, full-page ads in the *Wall Street Journal*, and direct marketing. New companies will also enter the marketplace through ongoing mergers and acquisitions in the electricity, gas, and telecommunications industries. EPRI's Karl Stahlkopf noted in a recent *Electricity Journal* article that "AT&T has developed a retail energy portfolio that it is planning to introduce as part of a diversification program. The company is expected to be a powerful competitor in the coming utility services convergence because of its marketing expertise and its brand-name recognition."

Californians won't be making the deregulatory leap alone. A number of retail electricity pilot programs have been running since mid-1996, primarily in New England and Illinois; these pilots are expected to expand significantly in 1998. Other states—including New York, Pennsylvania, Rhode Island, Oregon, and Washington—are planning a move toward full deregulation in the next few years.

No one can say for sure what the electricity industry will look like even five years after the competitive "big bang." One certainty stands out, however. Prices will drop. Prices in the pilots mentioned above have already dropped by 5–15%, and this dynamic has also been demonstrated in other deregulated American markets.

In the natural gas industry, for example, prices, adjusted for inflation, fell by 37% between 1985 and 1996; in the preceding decade, by contrast, gas prices had risen 71%. Prices have also dropped in the American telecommunications industry and in deregulated electricity markets in England, Wales, Australia, New Zealand, Chile, and Argentina. In fact, to position themselves for retail competition, many U.S. utilities have already frozen retail electricity prices, and in the short run at least, customers should see even lower prices.

Another certainty is that suppliers will no longer be protected from their own costs. That is, they will no longer be able to pass on the cost of doing business—plus a reasonable markup—to their customers. For the first time, it will be possible to lose money selling electricity.

Anticipating this shift, incumbent utilities have been moving to cut costs. Most have been downsizing, reengineering their operations, and negotiating more favorable contracts with power generators. At the same time, utilities are moving to develop new end-use products and services to provide greater value to customers. All these measures will be necessary to remain competitive in the newly freed-up market. But they won't be enough by themselves to confer long-term competitive advantage, since new-entrant suppliers will be doing the same things. In effect, these measures will keep utilities on the playing field but won't be enough to ensure that they win the game.

Marketing, and in particular pricing, will turn out to be a vastly more important determinant of success. Says Ahmad Faruqui of EPRI's Power Markets & Resource Management Business Area, "The successful pricing of electricity will separate the winners from the losers. Not surprisingly, energy companies are paying big money to lure financial talent from Wall Street and elsewhere to help them develop this core competency." To master the pricing skills needed in the new business environment, incumbent utilities will have to discard a number of long-valid assumptions and learn some brand-new concepts.

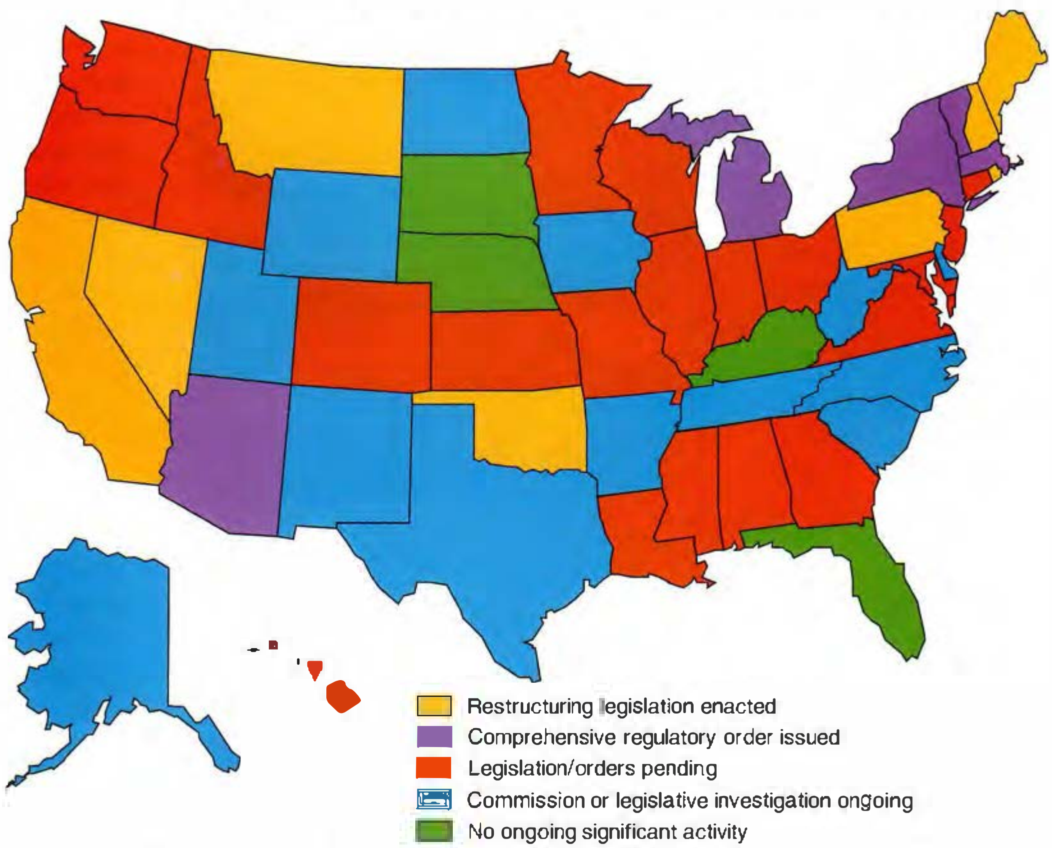
Costs: only one of many drivers

Consider the last item you purchased in a grocery or department store. Was your decision to buy the item based on whether you felt the supplier's costs justified the price? Or did you simply feel that this item was desirable in and of itself and was priced at a level you were willing to pay? The answer is obvious: in a retail market, customers don't factor a supplier's costs into their purchasing decisions.

This is a new way of thinking for the electricity business, where prices have been based exclusively on suppliers' costs. Except for competitive pressures, there is no inherent reason in a deregulated market why a supplier might not charge customers three or four times the cost of the electricity they receive. Nor is there any inherent limitation on pricing below cost for a limited period of time. For example, a supplier may choose to do this to gain a foothold in a new market while moving forward on a downward-sloping average cost curve. Or a supplier may price below cost in an existing market to make it unattractive for new entrants, as is happening in the telephone industry.

Once we accept that the link between cost and price has been changed, yet another industry assumption comes into question—the relationship between profitability and market share. A basic assumption of many industry managers is that high market share is automatically a good thing and that the inevitable customer erosion associated with competition is a bad thing—a negative trend against which they will have to fight a constant holding action.

This disinclination to lose customers,



STATE OF PLAY The country is moving steadily, if unevenly, toward electricity restructuring. Eight states have already enacted deregulatory legislation, with starting dates ranging from 1998 to 2002. (Source: U.S Department of Energy, Energy Information Administration.)

while understandable, is wrongheaded in a competitive retail environment where there is no built-in virtue to having 100% of the market. Companies in other industries often see their profits increase when their customer base decreases, as long as they are able to retain their most profitable customers. For example, recent EPRI research shows that profitability in the airline industry is associated not so much with overall market share as with the share of business passengers, who pay two to three times what pleasure travelers do.

If cost is no longer a basis for pricing and if market share—in and of itself—is no longer a basis for strategy, what new business concepts will replace these once-valid assumptions? The question leads us toward the concept of market segmentation and multiple pricing packages. First, though, we must take a look at how risk is entering the market and how risk will transform pricing.

From "flip-the-switch" to real-time pricing

Most customers currently receive electricity under what may be described as flip-the-switch pricing; that is, they receive their electricity any time they want it, in unlimited amounts, at a fixed rate. Under this arrangement, customers don't bear any risk at all, and neither does the supplier, since regulators protect incumbent utilities from losses. Flip-the-switch has long been a predictable, stable—and, for suppliers, reliably profitable—pricing mechanism.

Under the new rules, however, the risk implications of new business depend heavily on a retail supplier's overall portfolio. In particular, flip-the-switch pricing can become a risky way of doing new business, since suppliers have only limited control over the cost of the additional electricity they purchase to support this new business. Comparative data from the New York Mercantile Exchange on futures contracts suggest that in the United States, electricity is likely to be the most volatile of widely traded commodities. Typical price volatility for a stock fund is about 25% and for natural gas about 50-60%. Indications are that price volatility for wholesale electricity will be more than 100%.

In this rough-and-tumble market, supply and demand will determine the wholesale price of electricity, which will be set by an independent price pool operator and adjusted on an hourly basis. Over time, this period may shrink to half an hour—as it already has in England, Wales, and Victoria, Australia—and then to 5 minutes. In this new scenario, flip-the-switch goes from a utility's dream to a supplier's nightmare, one in which all risk is borne by the supplier and none by the customer. And even riskier for the supplier is a fixed-bill option now being created, whereby the customer is guaranteed a flat monthly charge no matter how much electricity is used.

The other risk extreme for additional retail sales can be described as real-time pricing, or spot pricing, in which the supplier simply passes on the fluctuating cost of electricity to consumers. Under this arrangement, customers bear all the risks and a supplier bears none. Such a contract would allow utility managers to sleep better at night—at least until their customers, enraged at the total lack of predictability in their electricity costs, switch to another supplier.

Thus flip-the-switch pricing and real-time pricing sit near the opposite ends of the risk spectrum. In reality, once market-based pricing kicks in, each product in its pure form will be largely a theoretical proposition. Particularly in the early years of deregulation, many customers will prefer something like a traditional flip-the-switch arrangement, but they will have to pay a premium for this price security and to accept time and possibly quantity limits in their contracts. Larger customers may be willing to accept the risk of real-time pricing, gambling that they will come out ahead over time. But even these customers will want some kind of protection from severe price spikes. Most pricing packages, in the end, will fall somewhere between the two risk extremes.

Persuading customers to accept risk, particularly residential customers and small and medium businesses, will be an interesting challenge. Current EPRI research, carried out through a tailored collaboration project, shows that customers, while not really clear on how deregulation will affect them in other ways, do expect lower electric bills. At the same time, many say they prefer a low fixed rate, are skeptical of contracts more than a year in length, and are even more skeptical of fluctuating prices that expose them to the vagaries of the market. Essentially, they're looking for something like the status quo—but cheaper.

Educating the consumer through clear price and contract signals must therefore be part of the suppliers' new marketing efforts. The process, in fact, has already begun. Chris Holmes of UtiliCorp points out that many large customers have approached utilities asking for better rates; once they understand the trade-offs involved, these customers have usually been willing to accept a certain amount of risk exposure in exchange for lower prices and/or other electricity features. The challenge for suppliers, says Holmes, will be to keep the focus on the benefits to customers of accepting risk in one form or another. Over time, he says, customers will become more comfortable and more familiar with the uncertainties inherent in the retail marketplace.

Multiple-choice pricing: worth the effort?

According to Rich Goldberg of EPRI's Power Markets & Resource Management Business Area, one of the most useful ways an incumbent supplier can differentiate its once monolithic customer base is by risk tolerance and load-shifting flexibility. These differences can be used to design pricing packages that are both profitable to the supplier and attractive to the individual consumer. "Once suppliers begin offering the right combinations of prices and features," he says, "they will find their customers becoming surprisingly accepting of new offerings."

Goldberg refers to the risk spectrum as he explains how differentiated pricing packages will allow suppliers to capture various segments of the market. As noted, some customers will prefer a flip-the-switch arrangement (with some contract limitations), while others will ask for real-time pricing (with some price protection). Many customers, however, will want a combined product that is closer to the center of the spectrum. One such hybrid might be a spot-plus-forward arrangement, which features a fixed rate for a portion of a customer's consumption and pure spot pricing for the balance. The proportions of the hybrid would vary according to whether the customer is more conservative or more aggressive in terms of risk tolerance.

Some customers may be willing to accept spot pricing for all their electricity, but only if the arrangement includes a "collar"—a price floor and ceiling—to limit wild price fluctuations. Still other customers may be willing to accept a certain number of hours per year in which their power may be limited (curtailable power) or even totally shut off (interruptible power). These and other options can be combined and recombined to create an almost limitless number of individual packages. Successful suppliers will be those who create a broad range of offerings—with a broad range of trade-off configurations—so as to satisfy many individual market segments.

Goldberg acknowledges that creating multiple pricing packages will make life more complicated for incumbent suppliers. But there's no getting around it, he says, since many new-entrant suppliers have extensive experience in retail pricing and will be putting that experience to good use. He further notes that prices not only will have to be offered in multiple packages but will also have to be adjusted and rebalanced on a regular basis as customers' preferences change. Echoing this point, UtiliCorp's Holmes says that "rapid repricing will be a critically important skill for existing utilities. Repricing is also a good way to test what works and doesn't work for your customers. You can put a product out there, see if it flies, and replace it with something else if it doesn't."

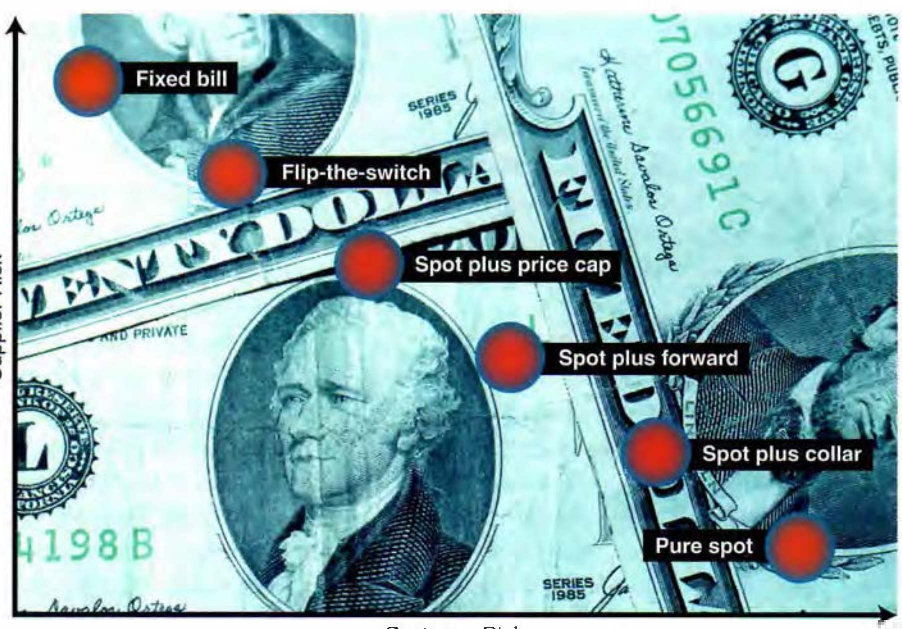
Jay Klompmaker of the Kenan-Flagler Business School at the University of North Carolina, Chapel Hill, concurs. At a workshop sponsored by EPRI's Retail Market Tools & Services Business Area, he suggested that "all else being equal, you make more money with more prices than fewer. There may be some costs in terms of customer confusion and price management, but as a general rule of thumb, the more prices the better. The reason is simple: variable prices allow you to maximize value from each individual customer segment."

Another element that will drive electricity pricing is the unbundling of the electricity industry. In the current market, American customers spend approximately $200 billion a year on an undifferentiated product that lumps together generation, transmission, distribution, customer service, billing, accounting, and ancillary services. The push is now on to break out these components and price them on an individual basis. All but two of the unbundled items—transmission and distribution—will be opened to competitive entry.

Industry observer Tom Taylor notes that while unbundling may squeeze out inefficiencies in the market, it will also introduce a host of new complexities. Taylor questions whether the market is really ready to handle a fully unbundled electricity product. "To get absolutely the best rates, customers will have to shop separately for each component. Some big customers will be willing to do this, but when most customers realize how much work and attention will be required, they'll be looking for a partially bundled or even entirely rebundled pricing product. Ultimately this will be another way in which the market will split into different segments."

All of this is directly relevant to pricing. Customers will judge the attractiveness of newly created pricing packages not only on the basis of individual price levels but also on the basis of which electricity components the packages cover. Smaller customers in particular will be willing to pay a premium for simplicity in their billing.

Unbundling and rebundling will create new opportunities to maximize profits, but only if suppliers move quickly to discern



RISKY BUSINESS Under deregulation, flip-the-switch (fixed-rate) pricing will be replaced by a variety of pricing packages spread along a risk spectrum. Once reliably profitable, flip-the-switch will become risky for suppliers; even riskier for them will be a fixed-bill option guaranteeing the customer a flat monthly charge regardless of electricity use. At the other extreme, pure spot (real-time) pricing will shift risk to customers. Most real-world pricing packages will fall somewhere in between.

the most current desires of their customers and to put together price and component packages that satisfy those desires. Once again, this is a strong argument in favor of suppliers offering their customers a wide range of choice.

Competitor dynamics

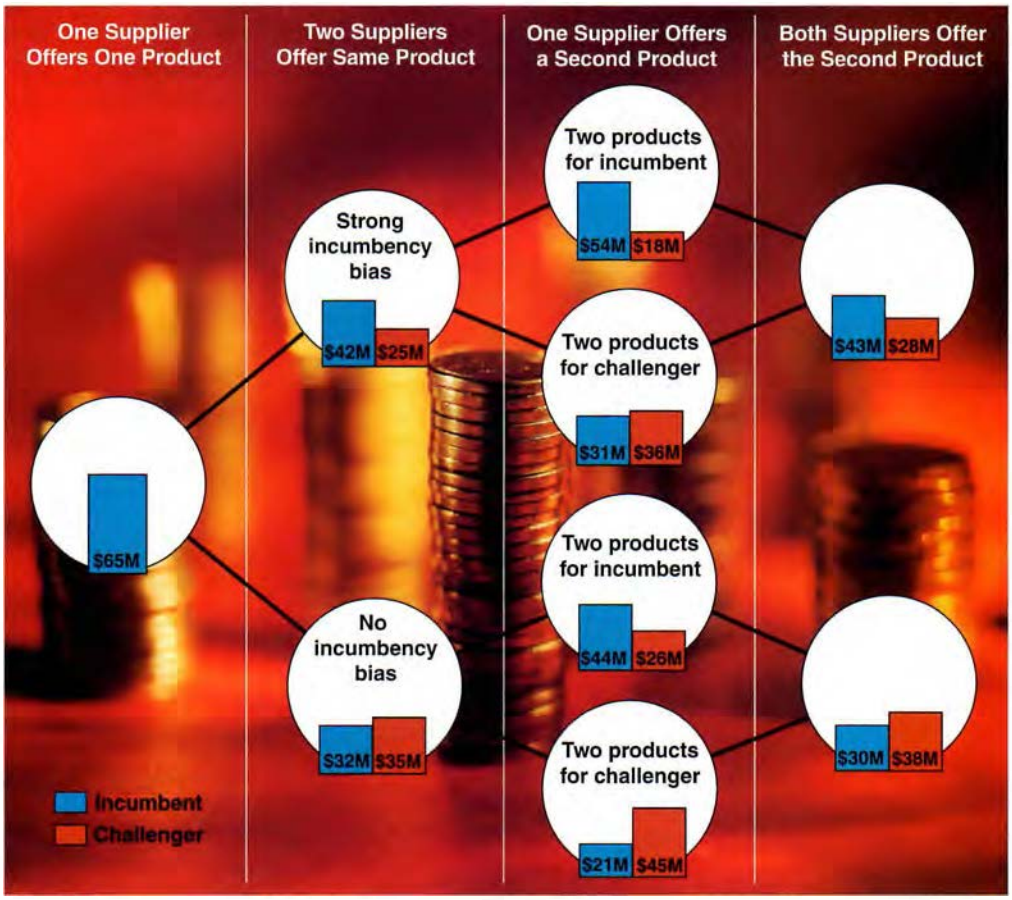
So far the discussion of pricing has largely ignored the new players hovering just outside the door, who intend to join the electricity party on January 1. These new competitors will fill the market, at least for a time, with more retailers than it can reasonably sustain. And their presence will change the current, relatively comfortable bilateral relationship between a utility and its customers. In the future, an incumbent utility will instead find itself in a triangle, with customers occupying the second point and new competitors the third.

EPRI's Ahmad Faruqui gives an example of how this triangle factor radically changed another market—that for luxury automobiles. Not so long ago, the luxury end of the market was controlled by Mercedes and BMW. Then the Japanese came in, redefined the market with sportier cars like the Lexus and the Infiniti, and took away a significant and very profitable customer segment. This forced Mercedes to lower prices on its popular E-class cars and to introduce the entry-level C class in an effort to regain lost customers and acquire new ones.

Likewise, Faruqui says, the electricity market won't simply be customer-driven; it will also be competition-driven. "Mercedes had been supplying value to its customers very successfully for a hundred years. Then, almost overnight, this wasn't enough because a competitor came in and re-created customer value in a new and desirable form. It isn't enough just to pay attention to your customers—you have to pay attention to your competitors as well."

The volatile mix of competition and customer choice will create a fast-moving electricity marketplace in which prices and products change continually. Marketing efforts that would once have seemed preposterous may become commonplace and successful, as long as customers perceive them as having value. Frequent-flyer miles, for example, rarely seem to fail when it comes to attracting customers. Or what about free electricity on Monday nights? For an example of a competition-accelerated marketplace, one must only look to the telecommunications industry, where new offerings and new entrants are continually parading across the stage. "About 30% of local telephone revenues now come from new products," Faruqui points out. "Before deregulation, customers would never have guessed that they would be willing to pay for these new products."

The dynamic nature of the coming marketplace is yet another reason why suppliers must create, field, and continually ad-



THE PUSH AND PULL OF COMPETITION **The entry of a competing supplier into the retail marketplace *will* decrease an incumbent utility's profits. In the example shown here, the incumbent, offering flip-the-switch pricing, loses customers and a substantial part of its former $65 million profit when a new competitor offers the same service at a slightly lower price; the degree of loss depends largely on incumbency bias—whether or not customers feel a strong loyalty to their traditional provider. In the next step, the incumbent or the challenger gains a strong advantage by offering customers a second, entirely new product, such as spot pricing. The resulting share loss prompts the one-product supplier to also add a spot price option. When both competitors offer the same two products at comparable prices, incumbency bias again becomes the dominant factor in customer and profit retention. Quantitatively modeling such market dynamics with EPRI's Product Mix software can help utilities develop successful retail products.**

just a sizable number of pricing packages. Incumbent utilities, as they work and rework these packages, will have to set aside some of their existing assumptions about what constitutes customer value. "You can't let preconceptions drive your strategy," says Faruqui. "If you do, a competitor without preconceptions will spot an unmet need, develop a new product or pricing package, and steal the customers you thought you knew."

Creating profitable pricing packages

The pricing concepts described above differ in many ways, but they have one thing in common: they are bound to increase the complexity of the pricing process. Generating a steady flow of innovative pricing packages that are both profitable and desirable will require formidable new technical tools. And most of these tools will have to be designed specifically with the electricity market in mind because, despite the fact that it will soon become a commodity product, electricity has a unique characteristic: unlike pork bellies or wheat, it cannot be stored in large quantities. The instantaneous nature of electricity will be another driver of pricing strategy.

No single tool, of course, will be sufficient to give suppliers a pricing edge, but EPRI has already done a good deal of work to help its members meet the new pricing challenge. One example is its Center for Electric End-Use Data (CEED), established by the Retail Market Tools & Services Business Area. This national clearinghouse sponsors extensive data collection, analysis, and modeling activities focused on customer load shapes. As a result, CEED provides a large database of hourly kilowatthour consumption data for most major residential and commercial markets. Rich Gillman, CEED manager, notes that load shapes will form an important foundation not only for pricing but also for forecasting, determining profitability, and other market-related functions.

Another example is C-VALU, a software package that lets suppliers "test-drive" retail pricing packages before launching them in the marketplace. C-VALU, operating on a real-time-pricing basis, allows a supplier to sift through a range of price and service combinations. By simulating customer load-shifting responses, customer participation rates, and net customer and supplier benefits, the software can help a supplier determine ahead of time

Meters, People, and Strategic Listening

Under the existing rules of the game, electricity customers aren't customers in the normal sense of the word. Rather they are ratepayers, most of whom receive electricity at a price determined by regulators. An incumbent utility playing by these rules may quite reasonably view its customers not really as individuals but more as electric meters—identical in nature and differing only in how much of the product they consume each month. One might further observe that existing utilities "own" these meters as part of their monopoly supplier status.

STEVE CAMPBELL

The introduction of retail competition turns this arrangement on its head. Utilities can no longer provide electricity on a take-it-or-leave-it basis, since they no longer own the customers in their geographic area. These customers can now choose from a range of other suppliers, many of whom will be offering attractive alternatives. Incumbent utilities must begin seeing their customers as individuals, not meters, and they must begin learning how to give them what they want at prices they're willing to pay.

EPRI's Ahmad Faruqui says, "The key to creating sustainable competitive advantage is strategic listening. That means gathering not just more information—which can lead to information overload and 'analysis paralysis'—but the right kind of information. In particular, suppliers need to gather data that are directly relevant to marketing and pricing strategies."

Faruqui points out that strategic listening goes well beyond the time-honored practice of monitoring customer complaints. Experience in retail markets shows that most customers are reluctant to complain about a product or service; if they have a choice, which electricity customers are about to receive, they would rather switch than complain. In addition, suppliers must listen strategically to their competitors. Given their existing skills and experience, what might new market entrants do to make an end run around an incumbent utility whose customers they want?

Faruqui concludes that the most important element of strategic listening is a transformation of mind-set and internal corporate behavior. "The information gathered can't be left sitting on a computer disk until the next annual planning session," he says. "Rather it must go directly to senior management in an actionable form so that price and product offerings can be continuously adapted and redesigned." □

whether a given pricing product is likely to be successful. Kansas City Power & Light used C-VALU to create a pair of new pricing options based on marginal cost. These options have now been deployed successfully in the marketplace, saving money for customers and promoting customer retention. KCPL forecasts substantial annual savings once these new products have been fully marketed.

A new EPRI software tool, Product Mix, brings competitors into the equation and also utilizes some of the new concepts in commodity finance that are pertinent to electricity pricing. Product Mix allows for the design and testing of multiple retail pricing options for various customer segments, with the goal of creating a line of attractive pricing products that will draw and keep valued customers. A new capability currently being developed for Product Mix will allow incumbent utilities to factor in the likely tactics and responses of their real-life competitors. This will make possible the simulation of a truly dynamic pricing market where all three groups in the triangle—customers, suppliers, and competitors—interact.

These products allow users to create virtual realities by simulating future markets. The simulations are calibrated to four real-world factors: the experience of other countries with competitive power markets, the experience of recently deregulated U.S. industries (telecommunications and natural gas), the experience of other highly competitive U.S. industries (computers and automobiles), and customer surveys about new electricity products and services. Each product is designed to help users create their own future rather than leaving it to chance. Originally developed for electric utilities, the products are being broadened to include other energy forms and to appeal to other players in the energy arena. EPRI provides training courses to support the implementation of these and related software products.

Additionally, EPRI will be sponsoring a major conference on innovative approaches to electricity pricing in June 1998 in Washington, D.C. Entitled "Pricing in a Competitive Electricity Market," the conference will provide participants with a comprehensive look at current research and thinking on electricity pricing in the deregulated era.

Finally, in the fall of 1998, EPRI will publish a book on pricing in a competitive environment, to be edited by Faruqui and by Bob Malko of Utah State University. The book will feature contributions from senior managers of incumbent utilities, new market entrants, customers, government personnel, investment bankers, researchers, and executives who work in industries where customer choice already drives pricing strategies.

The good, the bad, and the uncertain

According to Bob Leone of Putnam, Hayes & Bartlett, every supplier competing in the deregulated electricity market will be facing an uncertain transition period in which pricing will play a critical and steadily evolving role. "The bad news," he says, "is we don't know how to sell electricity, but the good news is our customers don't know how to buy it. We're all learning. So we can expect that pricing's role as an educational tool is going to be very important, both for customers and for sellers. We can study things, but we're going to have to do a lot of experimenting."

Suppliers, of course, will build their own learning curve into their evolving pricing strategies. But they will also have to build in the learning curve of their customers. In the initial phases of deregulation, product offerings may need to be relatively simple in order to gain acceptance. As time goes on and consumers begin to understand the benefits and trade-offs of retail electricity, they will accept and even demand increasingly sophisticated options.

The years ahead, inevitably, will be turbulent for incumbent utilities; this turbulence will simply arrive a bit sooner in California than it does in the rest of the country. Even if utilities use all the pricing concepts and tools at their disposal—and dump the preconceptions and tactics they no longer need—they may find it difficult to maintain profits during the initial shakeout period.

Over time, however, incumbent utilities will learn how to play the pricing game; many U.S. companies are already jump-starting this learning process by acquiring companies in England, Wales, Australia, and New Zealand. After even a year or two of competition, incumbent utilities will have gained incalculable new pricing skills. And they will be poised to move forward into a more stable and less crowded competitive marketplace, one in which profits will be allowed to rise above regulated levels and deregulation may actually be something to cheer about. ■

Further reading

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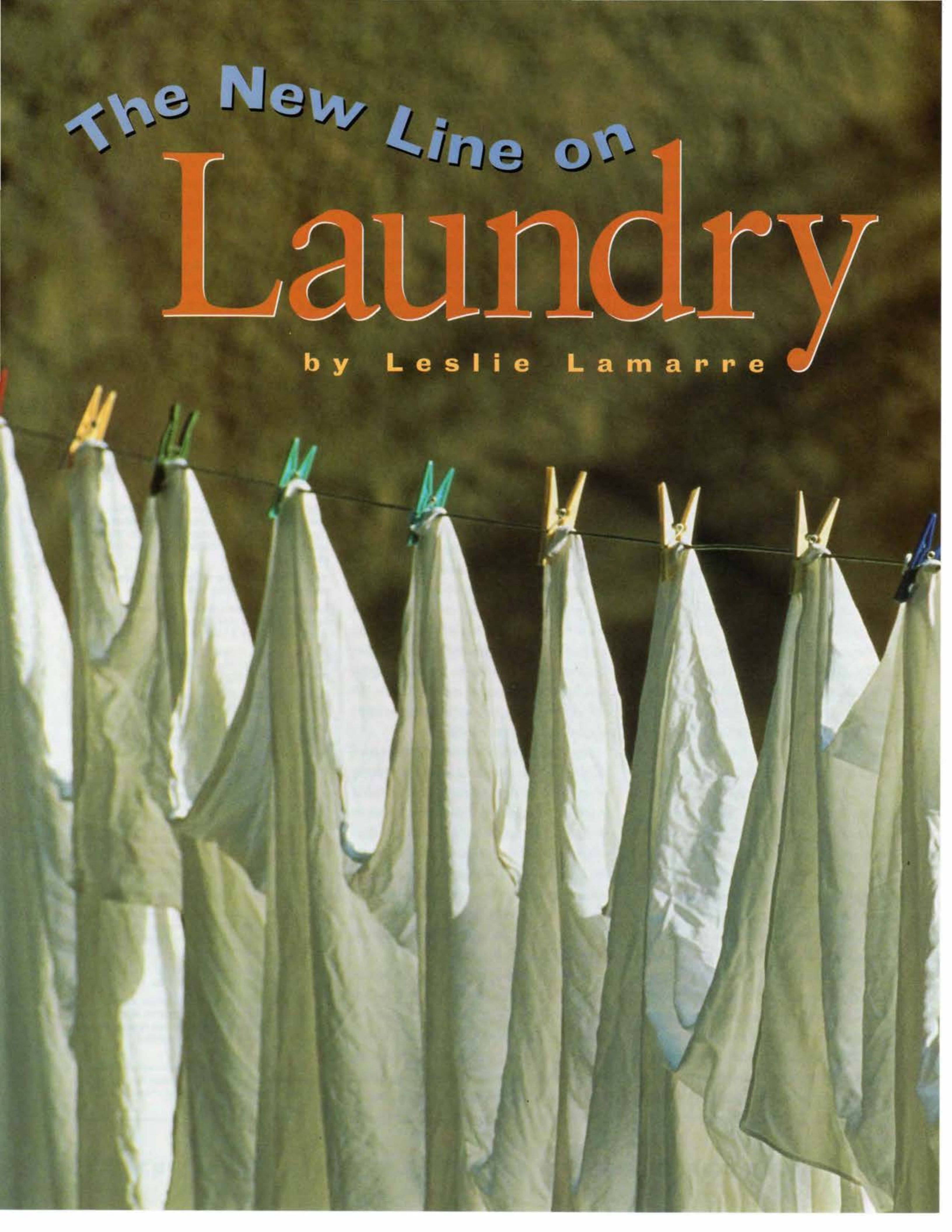
Background information for this article was provided by Ahmad Faruqui and Rich Goldberg, Power Delivery, and Paul Meagher, Customer Systems.

The New Line on Laundry

by Leslie Lamarre



New front-loading washing machines released by U.S. manufacturers are revolutionizing the laundry market. And EPRI researchers have another innovation in store—the countertop microwave clothes dryer.

BROWN BROTHERS

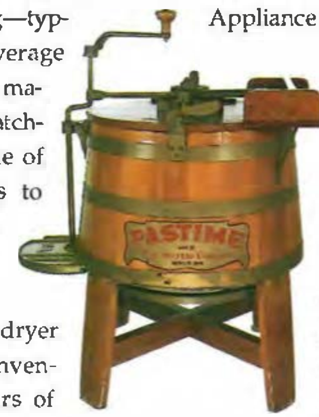
THE GRANGER COLLECTION, NEW YORK

THIS JUST MIGHT BE the most exciting time in laundry since the arrival of the automatic washing machine. Three of the five major U.S. appliance manufacturers introduced front-loading clothes washers within the past year. Not only do these machines clean clothes better than the average top-loading washers, but they save energy and water in the process. And despite their hefty price tag—typically at least twice the average cost of top-loading U.S. machines—consumers are snatching them up. At least one of the manufacturers plans to expand production facilities to keep up with the demand.

The American clothes dryer too is on the brink of reinvention. After several years of research and development aimed at introducing a full-size microwave dryer, EPRI has taken a different tack and is now pursuing a countertop version with a far broader market potential. The new dryer could hit the market as early as the end of next year.

"There's a market transformation going on right now," says John Kesselring, who manages EPRI's research on laundry appliances. "We're talking major changes in the way America does its clothes—the biggest changes that have come down the pike in 30 years."

Admittedly, the realm of laundry appliances has not been a fountainhead of innovation in recent decades. The biggest news came early this century, when the electric motor was added to the standard wooden-tub machine to power the previously hand-cranked agitator. By the late 1920s, washing machines were manufactured in metal, but water still had to be heated externally and poured into them. It wasn't until the 1950s that washers were introduced that could heat water in the tub electrically. And finally, in the 1960s, came automatic control of the entire washing process, so filling, agitation, rinsing, and flushing could all be set and timed by switches.



WASH DAY Washing machines have been top-loading since the days of wooden tubs with hand-cranked wringers. Shown above on the right is Maytag's first washer (1907).

Little has changed about the washing machine since that breakthrough, which is partly why the appliance industry is now abuzz with excitement. "The appliance business can get boring," concedes Don Heitlauf, who owns Crossroads Appliance in Bellevue, Washington, and has been selling major appliances for two decades. "Now we have something new and exciting to show people who come in." Heitlauf, who carries the new U.S.-made front-loading machines as well as some European models, says the American models introduced in the past year have been a big hit. In fact, he reports, 49.4% of all the washers he sold in September were front-loaders, compared with less than 3% for the same period last year.

Roots of excitement

The front-loading washing machine is nothing new. Better known in the technical community as the horizontal-axis machine because its tub—like the drum of a clothes dryer—rotates around a horizontal axis, this style of clothes washer has long dominated the European market. In the United States, front-loading Bendix machines found their way into a few homes after World War II, but leak problems gave the machines a bad name. The modern European models have not made great headway in the U.S. market because they generally have a smaller capacity and a longer wash cycle than the average U.S. machine and are much more expensive—typically costing at least three times as much. However, they do save energy and water.

Unlike the top-loading, vertical-axis machines that account for 98% of the U.S. residential market, horizontal-axis machines have no agitator. Rather than pushing and pulling clothes in a full tub of water to clean them, horizontal-axis machines use drum rotation to dip and lift clothes into and out

PHOTO PAGES 14–15 © 1997 WALTER BIBIKOW/THE IMAGE BANK of a shallow pool of water in the bottom of the tub. Because about 85% of the energy consumed by a washing machine goes toward heating the water, using less water saves energy. EPRI studies show that horizontal-axis machines use about a third less water and about two-thirds less energy than standard vertical-axis machines.

Such efficiency advantages were the incentive that prompted U.S. manufacturers to develop front-loading machines. Several years ago, the U.S. Department of Energy announced that it intended to issue more-stringent energy efficiency requirements for washing machines. "In order to meet the anticipated requirements, it was obvious to manufacturers that they'd have to go with a horizontal-axis design," says Kesselring. While washer manufacturers debated among themselves about how strict the energy requirements should be, they individually got down to business.

In the midst of all this research and development, DOE temporarily shelved its plans for more-stringent standards. The plans have only recently been revived, and

Frigidaire's Gallery

LAUNDRY LIST **Frigidaire, Maytag, Amana . . . One by one, major U.S. appliance manufacturers are introducing high-efficiency front-loading washing machines to the residential market, joining the ranks of European makers—like Miele—that have been producing them for decades. One big attraction for consumers is the often-superior cleaning ability of front-loading machines. Shown here are cloth swatches from a study sponsored by EPRI and Maytag.**

Amana's LTA85

Miele's front-loading laundry system

Original grass stain

After washing in Maytag's Neptune

After washing in a leading top-loader

COURTESY MAYTAG

Maytag's Neptune

the new standards are now slated to be released in 1999 and to become effective in 2002 or later. Needless to say, manufacturers are ready. The front-loading machines currently on the market are Frigidaire's Gallery, released last fall; Amana's unit, which came out this fall; and Maytag's Neptune, developed in partnership with EPRI and released in July (see sidebar, page 22). Whirlpool has announced that it too is developing a high-efficiency washer. General Electric, the only other major U.S. washing machine manufacturer, has not yet announced any such plans.

What matters most

While the new front-loaders may be environmentally correct, this attribute is not the big attraction for U.S. consumers. What motivates them is that the horizontal-axis machines can get clothes cleaner with less wear and tear on fabrics. Consumers also like the absence of the agitator, which frees up room for comforters, rugs, and other bulky items they might otherwise have to take to the laundromat.

These are just some of the insights gleaned in a four-year EPRI study—the High-Efficiency Laundry Metering and Marketing Analysis, or THELMA, project. Funded by a consortium of 29 electric, gas, water, and wastewater utilities and government agencies, THELMA was initiated in 1993 to gather critical information needed to support a successful market transformation to high-efficiency clothes washers. Through a series of consumer focus groups, a national telephone survey, in-home tests of horizontal-axis technology, and a demonstration center where consumers got to try the machines out for themselves, researchers learned a lot about the laundry habits of U.S. families and their attitudes about washing machines.

One overriding conclusion of THELMA is that the existing washer market certainly isn't easy to crack. At this time, 84% of consumers are very satisfied or somewhat satisfied with their own washing machines. Their biggest complaints are unbalanced loads and clothes tangling around the agitator. Consumers surveyed showed very low awareness of horizontal-axis technology. Many thought the technology was obsolete or associated it only with the laundromat. One of their primary concerns about front-loading washers was whether the machines could handle the same amount of clothing as their top-loading washers. Another concern was the inconvenience of having to bend and stoop while loading and unloading clothes. Consumers also had to be convinced that the front-loaders could clean as well as top-loaders, given that they don't have agitators.

THELMA's in-home tests and the demonstration center trials helped quell some of these fears. During the in-home tests, 50 households in the Pacific Northwest got to use horizontal-axis machines for their usual laundry over a seven-week period. Researchers then compared the resulting data with data from an earlier six-week period during which consumers had used their regular machines. (An extra week was allowed with the new machines so that the test participants could familiarize themselves with the technology.) All the participants used calibrated laundry baskets to track the size of wash loads. The tests indicated that the capacity concern was more visual than actual; once the consumers got used to stuffing the horizontal-axis machines full, they typically washed loads as large as the ones they wash in their own machines. Further, a number of participants said their clothes

MAJOR ATTRACTION Electric utilities across the country are helping to promote the sale of energy-efficient washing machines through marketing campaigns and rebate programs.

COURTESY PUGET SOUND ENERGY

COURTESY SMUD

COURTESY PACIFIC GAS AND ELECTRIC CO.

were cleaner and brighter when washed in the new machines.

THELMA also documented water and energy savings. Water savings with the horizontal-axis machines ranged from 11% to 74% per load, with average savings of 36%. Energy savings are much more complex and depend on warm and hot water use, among other factors. The average energy savings calculated in THELMA were 64%. This figure reflects savings related to hot water use and to the washer motor. It does not include the energy savings from the shorter drying time made possible by a washer's high-speed spin cycle. (Two different horizontal-axis models were used in the in-home tests—one with and one without a high-speed spin cycle.) Overall, THELMA showed that the typical family, with 6.7 loads per week, could save anywhere from $43 to $106 per year on energy, water, and wastewater bills.

Price factor

By the end of the seven-week trial period, 46% of the in-home participants preferred the horizontal-axis machines to their own. But the number that said they wanted to buy one is another story—only 22%. The biggest barrier cited was the cost of the machines. Indeed, the new front-loaders on the market are priced between $600 and $1000—well above the $220–$550 range for conventional, top-loading machines.

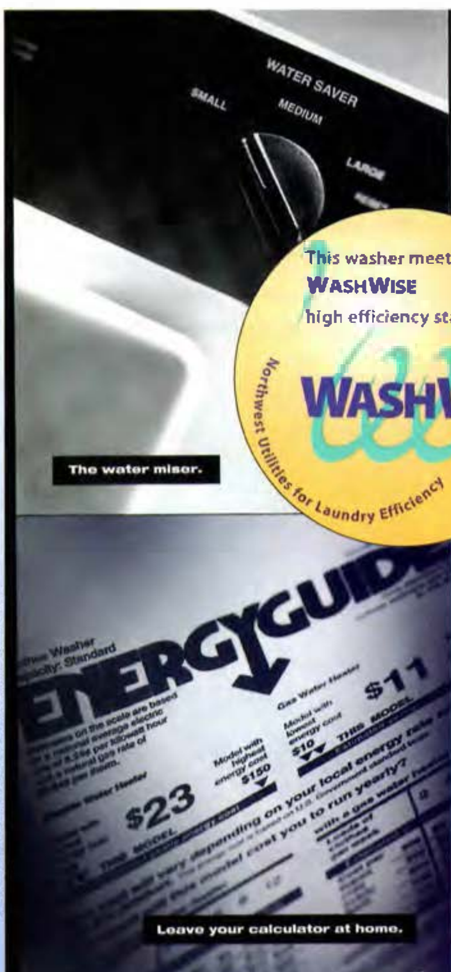
Despite these research findings, however, horizontal-axis machines appear to be faring quite well in the marketplace. Linda Eggerss, manager of marketing and media relations for Maytag, reports that the residential version of the Neptune washer "is flying off dealer floors." Says Eggerss, "We're kicking them out the door as fast as we can."

Like other manufacturers, Maytag does not make the number of product sales public. But Eggerss says that to keep up with Neptune orders, workers in the Newton, Iowa, factory where the machine is built have regularly been putting in overtime. She adds that the company has committed "significant capital" to expanding Neptune's existing production lines. "It's turning out to be a far easier sell than anyone in the industry would have anticipated," says Eggerss, noting that customers have commented on the product's ease of use, its quietness, its ability to clean clothes better than top-loading machines, and its gentleness on clothing.

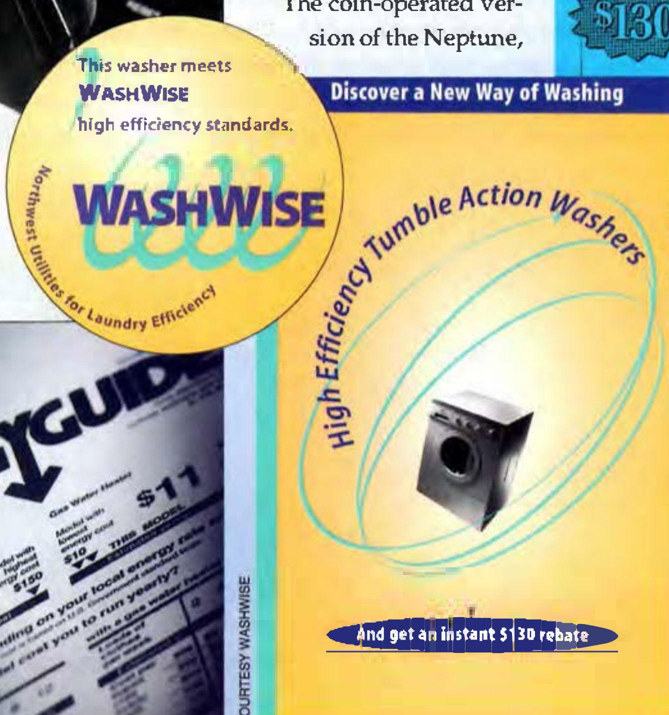
The coin-operated version of the Neptune, which is identical to the residential unit, is also selling well. According to Eggerss, the number of commercial orders for this machine in the first month of its release last March was greater than the number Maytag expected to sell in the product's first year.

"This just goes to show that people will buy a thousand-dollar machine if they are convinced the benefits are real," says Kesselring of EPRI. Maytag's front-loader offers consumers some unique attributes, like a wide-mouthed, ergonomically designed tub, which is tilted at a 15-degree angle for easier access, and a high spin speed in the final cycle, which cuts down on drying time. In addition, the machine's superior cleaning ability has been documented in thorough comparison cleaning tests cosponsored by Maytag and EPRI.

For these tests, Maytag used swatches of cotton cloth, each evenly soiled with a single stain. There were eight types of stains in all—grass, blood, "ring around the collar," chocolate milk, beef gravy, spaghetti sauce, grape juice, and clay. The stained swatches were attached to garments and washed in loads of equal size in four top-loading machines (sold under the General Electric, Kenmore, Whirlpool, and



COURTESY BONNEVILLE POWER ADMINISTRATION



COURTESY WASHWISE

COURTESY WESTERN APPLIANCE

Maytag labels) and in a Neptune. A spectrocolorimeter—a handheld instrument that looks much like a price-scanning gun with a computer screen—measured the brightness of the fabrics both before and after washing. The results showed that the Neptune cleaned better than all the top-loading machines for all eight types of stains. Cleaning by the Neptune was significantly better than that of the other washers for blood, grass, and ring around the collar. A statistical analysis showed a confidence level of close to 100% for these results.

One drawback of the new front-loading washers is their slightly longer washing time—between 44 and 55 minutes, compared with 36 minutes for a standard washer. Additional rinse cycles and soaking time account for this difference, which nevertheless represents a considerable improvement over European front-loaders. The wash cycle of European units that heat their water internally can run as long as 2 hours.

To help the U.S. market warm up to high-priced, high-efficiency washers, some utilities are offering rebates on the new machines. As part of a national initiative organized by the Boston-based Consortium for Energy Efficiency, nearly 30 electric, gas, and water utilities serving 16% of the U.S. residential market are promoting the high-efficiency models through marketing campaigns, washer demonstrations, and rebate programs.

A consumer inspects Maytag's Neptune in the showroom of Crossroads Appliance of Bellevue, Washington.

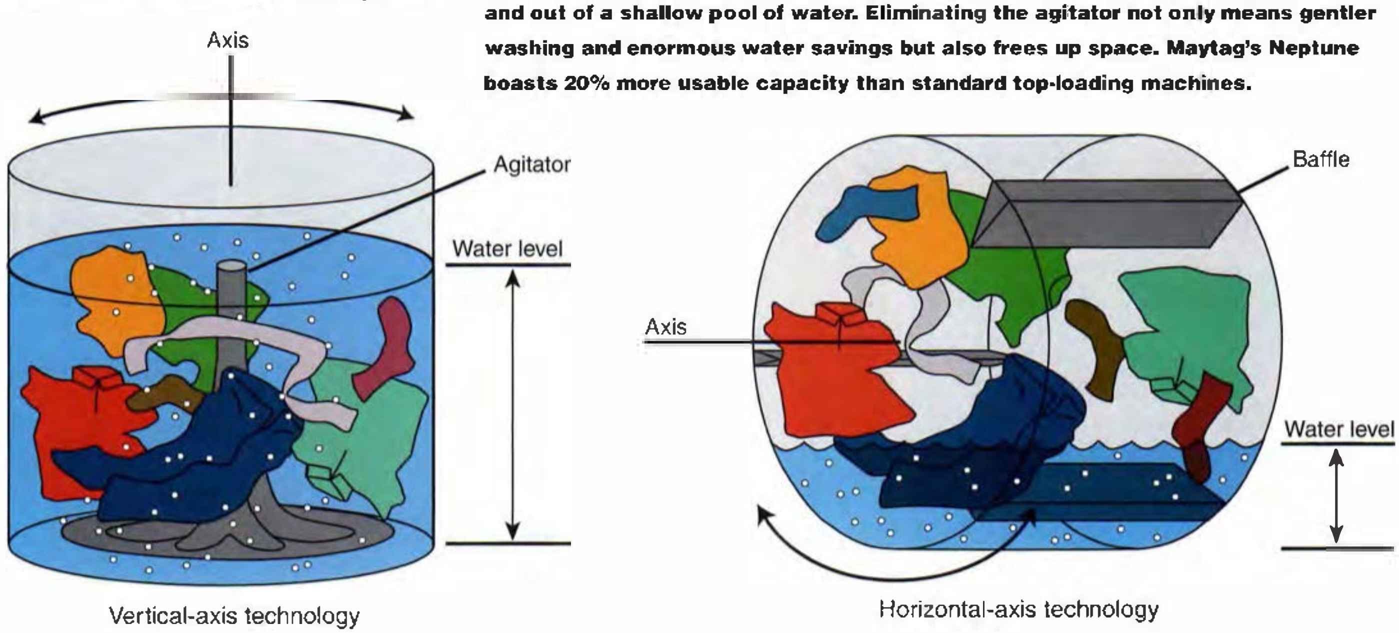
One of the most successful campaigns in this initiative is a regional program called WashWise, which was launched early in May by electric, gas, water, and wastewater utilities in the Pacific Northwest. Through this program, customers typically get a $130 discount off the purchase price of qualifying washer models. For each unit sold, the retailer gets a $20 incentive. The idea is to encourage retailers to display high-efficiency washers and relevant marketing materials prominently. Both the customer discount and the retailer's incentive are paid by WashWise. In some areas, customers can get an additional cash rebate of up to $75 from participating water or wastewater utilities. In the first five months of its existence, WashWise processed 5654 rebates.

Drying time

EPRI's washer-related research has progressed in parallel with research aimed at improving the drying side of the laundry cycle. For seven years now, EPRI has pursued the development and commercialization of a microwave clothes dryer. The technology is expected to be as much as 65% faster than conventional drying technology, which is inherently inefficient.

In a conventional dryer, air is heated to

WASHING WITHOUT AGITATION Missing from the new energy-efficient front-loading washing machines on the market are agitators—a fundamental washing mechanism in standard top-loading washers. Instead, the new washers (technically known as horizontal-axis machines) rely on drum rotation and baffles to dip and lift clothes into and out of a shallow pool of water. Eliminating the agitator not only means gentler washing and enormous water savings but also frees up space. Maytag's Neptune boasts 20% more usable capacity than standard top-loading machines.



about 350°F, and the heat, once transferred to the surface of the wet clothing, evaporates the water. The later stages of drying are particularly inefficient; heat must penetrate the fabric's interior to vaporize the moisture there, but the vapor escaping from the fabric cools the material, which then must be heated again for the vaporization process to continue. Because of the need to actually heat the fabric, its surface gets as hot as 140–150°F. Such high temperatures can cause shrinking and reduce clothing life.

In microwave dryers, by contrast, microwaves penetrate the surface of the wet clothing and heat the water inside directly; thus the fabric stays cooler—typically getting no hotter than 110-115°F. A flow of warm air passing through the dryer carries away the evaporated moisture. Because the microwave drying process is both shorter and cooler than conventional drying, it's gentler on clothing. The shrinking of cottons is largely eliminated, and fabrics sensitive to heat, such as wool, can be dried in microwave machines.

Originally, EPRI pursued the development of a full-size microwave dryer. This multiyear effort culminated in the successful demonstration of prototypes and the winning of some coveted technology awards, including *Popular Science* magazine's grand award for home technology in 1994. About a year ago, however, EPRI shifted its focus to the development of a countertop model for specialized applications. The shift occurred when the two major appliance manufacturers that had shown the most interest in the microwave dryer technology over the course of EPRI's work decided not to go forward with the product's commercialization. "It was bad timing really," explains Kesselring, noting that the appliance makers had just spent $50 million to $100 million developing high-efficiency washers.

Still, the fruits of EPRI's labor on the full-size dryer may not be lost, since the R&D is directly applicable to the countertop, microwave-oven-size version. For example, EPRI developed and tested a solid-state sensor safety system for automatic shutoff in the event that a stray object such as a cigarette lighter threatens to scorch fabrics or start a fire. The system, which would also be deployed in the countertop dryer, works by detecting even small amounts of carbon monoxide, carbon dioxide, and other precombustion gases. A second sensor system, patented just this summer, detects humidity. This system automatically shuts off the machine when the clothes are dry, so there's no need for a timer and no energy is wasted overdrying clothes.

Just as with microwave ovens, the countertop dryer would supplement—rather than replace—existing technology. Consumers could use it both for smaller loads needed in a hurry and for delicate materials, such as nylons and silks, that could be damaged by a conventional dryer. Since the countertop dryer would be made up almost entirely of components already in use in today's microwave ovens (with the exception of the sensor systems and the rotating drum), its development and production would be relatively swift and inexpensive. As a result, its retail price—about $150, or roughly the same as that of a standard microwave oven—would be far lower than the $1000 a full-size microwave dryer would cost.

ZAP IT DRY EPRI has already developed a full-size microwave dryer and is now working on a countertop unit with a much broader market potential. Because microwaves can heat water molecules directly, the technology is inherently more efficient than conventional drying technology—and, as a result, as much as 65% faster.

Broader appeal

Whereas the full-size microwave dryer would likely appeal to an upscale niche market, the countertop model is expected to have a much broader market, including apartment dwellers, dormitory students, upscale hotels, and health clubs. Apartment residents, whose only access to laundry facilities may be a centrally located laundry room, could use the countertop microwave unit to dry delicate hand-washed clothing, such as nylons, wool sweaters, and silk shirts. Hotel guests, rather than waiting for hand-washed items to drip-dry, could dry them quickly and rewear or pack them. Dormitory students could zap damp towels dry and reuse them without heading to the laundry room. Health club members could pop damp bathing suits into the appliance for speedy drying.

EPRI recently completed a market study that showed a high level of consumer interest in the countertop microwave dryer. According to the study (TR-109116), expected to be published late this year, the potential U.S. market for this technology is some 100 million households, not to mention hotels, dormitories, and other locations. Working in favor of the technology are two problems consumers reported

The Neptune: One Machine's Evolution

MAYTAG'S front-loading Neptune clothes washer, introduced as a coin-operated unit to commercial laundries in March and as a residential unit to general consumers in June, is the result of a six-year partnership between EPRI and Maytag.

COURTESY MAYTAG

A worker at Maytag's Newton, Iowa, plant assembles the Neptune's inner tub.

In 1991, when the U.S. Department of Energy began considering increasing the efficiency standards for washing machines, Maytag approached EPRI about jointly developing a horizontal-axis machine. The project got under way in 1992. "Maytag had thought about a horizontal-axis washer for a while," recalls John Kesselring, EPRI's manager for the joint project. "They knew it was going to be a tough sell. What led them to go ahead was a combination of our showing an interest in doing this with them and their feeling that it was the right thing to do."

Even though horizontal-axis technology had been around for some time, there were many technological issues to address, such as providing the large capacity preferred by consumers, who tended to associate front-loading machines with smaller loads. With market insight and technical data obtained in EPRI's THELMA (the High-Efficiency Laundry Metering and Marketing Analysis) project, Maytag was able to address and resolve such pertinent issues.

Perhaps the most significant issue resolved was tub access. Through market research, Maytag learned that one of the biggest aversions consumers had toward front-loading machines was the need to bend and stoop to get laundry into and out of the tub. They also complained that the small size of the tub opening made loading and unloading awkward. Maytag and EPRI explored other alternatives, including a top-loading horizontal-axis machine with two doors. Dummy washers were prepared so that consumers could try them out and report on what they liked and didn't like. In the end, Maytag came up with an exciting innovation—a tub tilted upward at a 15-degree angle with an extrawide access opening. The ergonomic design resolved the bend-and-stoop problem without resorting to two doors. And the resulting tub has a capacity of 2.9 cubic feet—20% more usable capacity than in standard top-loading washers and also more capacity than in any other high-efficiency residential washer on the market.

Achieving such a large capacity in the residential machine was not easy, particularly since Maytag wanted to offer a super-high spin speed. Many of the European washers spin at 1000 rpm in the final cycle but have a tub that is rather small in diameter. The Neptune spins at 800 rpm, but because its tub has a large diameter, its water extraction force is about equal to that of the European models. This force is some 25–30% greater than that of the typical top-loading washer, and as a result, drying times are 25–30% shorter. Spinning a clothes load at 800 rpm can result in severe vibration and even "walking" of the washer if the load is not properly distributed in the tub. Maytag

having with conventional dryers: damage to clothing and the difference in cycle time between washers and dryers (a difference that would be eliminated with a microwave dryer). Also, conventional dryers are not used for as much as 30% of all clothing in consumers' households, and the study respondents said they were frustrated with the time, effort, and expense required for these special garments.

Such findings certainly favor the introduction of a "personal microwave dryer," as the technology has been dubbed. But this doesn't mean there won't be market barriers to overcome. Some consumers expressed concerns about the safety and effectiveness of microwave drying, and these people will need to be assured through educational programs and demonstrations of the technology.

It will be interesting to see who steps forward to manufacture the personal microwave dryer. EPRI's market study report says that laundry appliance manufacturers are not likely to be the first in line. Instead, manufacturers of other countertop appliances like microwave ovens are the ones most interested. In fact, the report states, these manufacturers "are presently investigating the technology as a means of expanding their product lines."

EPRI is currently talking with potential manufacturers and hopes to hook up with one early next year to produce a prototype of the countertop unit. The prototype will be developed and tested to meet the safety requirements of Underwriters Laboratories. Once this is accomplished, EPRI, in collaboration with its manufacturing part-engineers developed unique load distribution and vibration isolation technology that results in very quiet and smooth operation.

Another issue Maytag wanted to address with its new washer was the problem of excess suds. As EPRI's research showed, U.S. consumers are accustomed to using a full scoop of detergent in nearly every load. But detergents formulated for conventional, top-loading washers generate lots of suds, and using too much of one of them in a horizontal-axis machine can lead to oversudsing. In extreme cases, the concentration of bubbles can become so high that the clothes in the machine cannot move—a condition called suds lock.

Special low-sudsing detergents, now being released under brand names like Wisk and Tide, have been formulated for use in horizontal-axis machines and produce the best results. But Maytag wanted consumers to have the choice of using their regular detergent too, so researchers developed an electronic sensing system that detects and controls oversudsing. When the washer detects excess suds in the wash cycle, it automatically drains the sudsy water and substitutes fresh water. When the washer senses excess suds in the spin cycle, the machine reverts to the wash/rinse cycle to flush away the bubbles.

So far, the Neptune has received high marks for attributes important to most consumers, like comfort and convenience. Some users even appreciate the machine's environmental benefits. This summer in the water-starved farm community of Bern, Kansas, Maytag donated 103 washers for a U.S. Department of Energy–sponsored study. The study involved weeks of in-home washer monitoring, first of the participants' existing machines and then of the new Neptune machines. Digital monitors on each washer recorded the amount of water (hot and cold) and electricity used, while users dutifully weighed each load and recorded all relevant data on special forms.

AP/WIDE WORLD PHOTOS

Verona Strahm of Bern, Kansas, prepares to use one of the 103 washers Maytag donated to town residents for a U.S Department of Energy–sponsored efficiency study.

COURTESY MAYTAG

Maytag gathered TV moms from the previous four decades for a publicity event announcing its front-loading Neptune washer. Pictured here, with Gordon Jump (the Maytag repairman who never gets called), are June Lockhart of *Lassie*, Florence Henderson of *The Brady Bunch*, Barbara Billingsley of *Leave It to Beaver*, and Isabel Sanford of *The Jeffersons*.

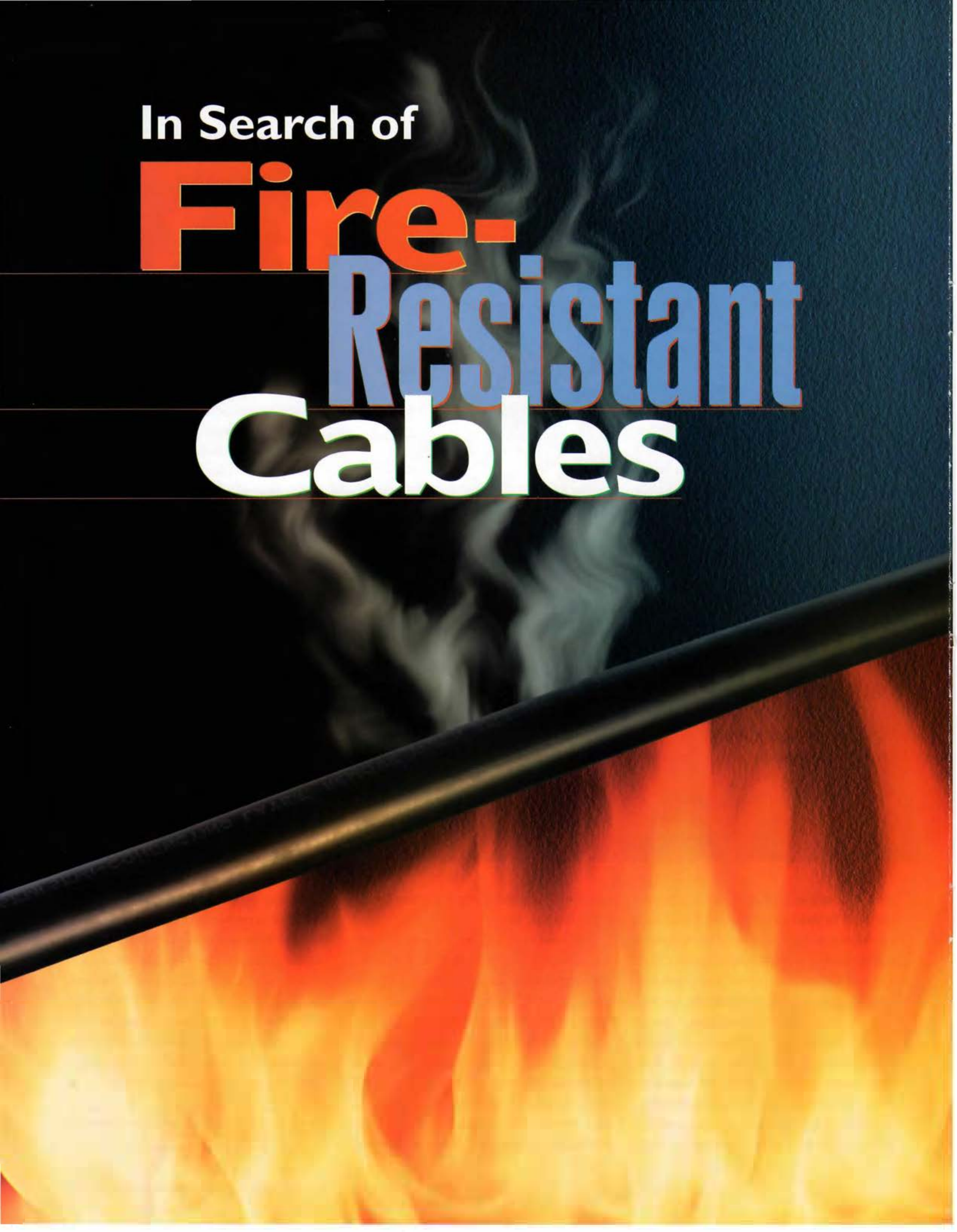
Two times during the study, once with the old machines and once with the Neptunes, all the participants saved up a week's worth of laundry and washed it on the same day. On the second of these "superwash" Saturdays, Maytag and DOE hosted a town celebration, at which they announced the initial results of the comparison testing. The data showed water savings of 38% and energy savings of 56% with the Neptune washers. According to DOE, if only 20% of U.S. homes used high-efficiency washers such as those in the Bern study, Americans would save more than 26 billion gallons of water a year and enough energy to heat 800,000 homes. □

ner, will produce a small number of dryers that will be field-tested before the dryer's production phase. Because of the extensive testing and component development that have already taken place, the product's introduction would be relatively speedy. "The dryer could be in consumers' hands within 12 months of our signing on with a manufacturer," Kesselring predicts. This time frame assumes that the manufacturer's own testing—for product reliability, durability, and performance—goes smoothly. It also assumes that the manufacturer can swiftly assemble a production line to make the new unit.

EPRI hasn't given up on the idea of a full-size microwave dryer. In fact, a positive market response to the countertop model could pave the way for a full-size unit. Only time will tell precisely how receptive consumers are to both the horizontal-axis washer and the microwave dryer. But if both technologies make inroads, the impact could be significant, not just in terms of energy efficiency and water savings but also in terms of consumers' clothing budgets. As Kesselring points out, wearing, washing, and drying each account for one-third of the total wear and tear on clothing. Reducing the impacts of two of these three variables should make clothing look better and last longer. Says Kesselring, "We're hoping to help people save on their laundry bills and clothes budgets while showing how electronics can be of value to the average consumer in a very meaningful way." ■

Background information for this article was provided by John Kesselring, Customer Systems.

In Search of Fire-Resistant Cables



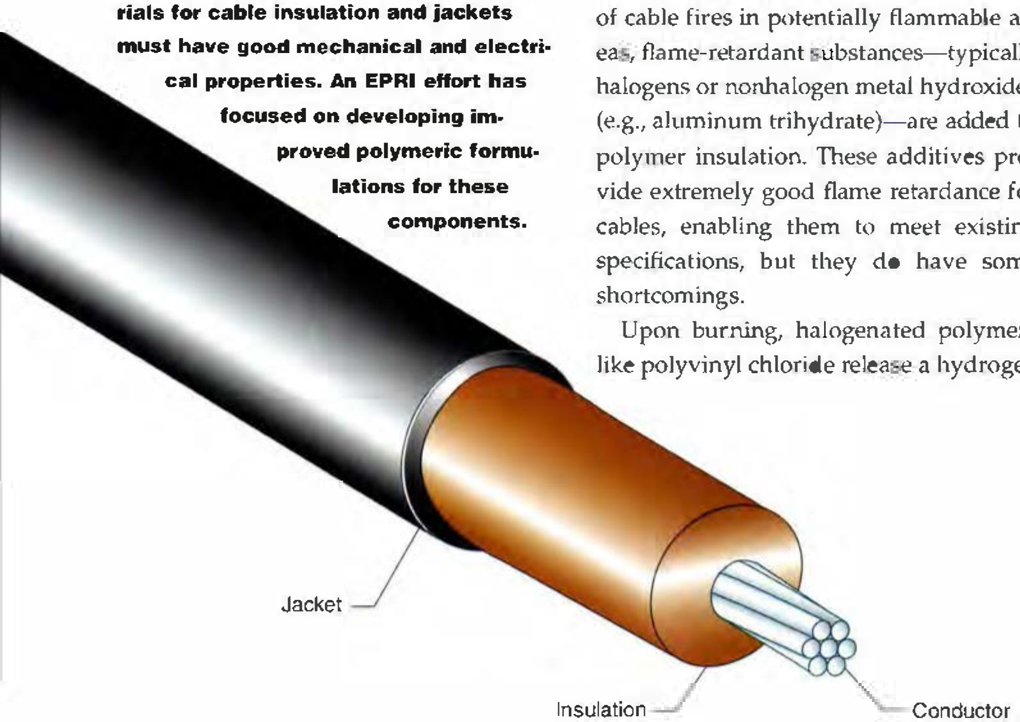
The Story in Brief Polymeric materials employed as flame-resistant cable insulation are not satisfactory in all respects, since some existing formulations—when ignited—produce large quantities of smoke and potentially corrosive chemical compounds. The utility industry especially needs new formulations for the flame-resistant polymer insulation used in low- and medium-voltage cables. EPRI's exploratory work in this area—an example of the value of basic research guided by strategic aims—has been conducted in close consultation with polymer manufacturers, chemical suppliers, cable manufacturers, and electric utilities. The research has produced two promising new flame-retardant polymer formulations, now being evaluated by a cable supplier for possible commercial manufacture.

by Joy Schaber

Perhaps the most versatile family of materials in existence, synthetic polymers consist of chains of repeating molecular units whose number and chemical structure determine the materials' properties. Many types of additives can be used to modify synthetic polymers, yielding a tremendous range of desired characteristics. Since the first formulations were produced at the turn of the century, polymeric materials have been put to more and more uses, from hair clips to space shuttle components. Polymer compositions are seemingly endless in number. The most recognizable are polyolefins, such as polypropylene and polyethylene, which are used in plastic bags, shampoo bottles, plant pots, trash cans, and thousands of other everyday products.

In the electric power industry, insulation for all transmission and distribution equipment—including cables, transformers, capacitors, insulators, and rotating machinery—is based on polymers. Polyolefins and olefin copolymers are the primary components of wire and cable insulation. Other common but less well known utility applications of polymers include separation membranes, advanced battery electrolytes, bodies for electric vehicles, corrosion-resistant coatings, piping, environmental control system components, and line workers' gloves and sleeves.

PHOTO PAGES 24–28 AND PHOTOS OF MODELS PAGES 26–28 BY WEINBERG & CLARK



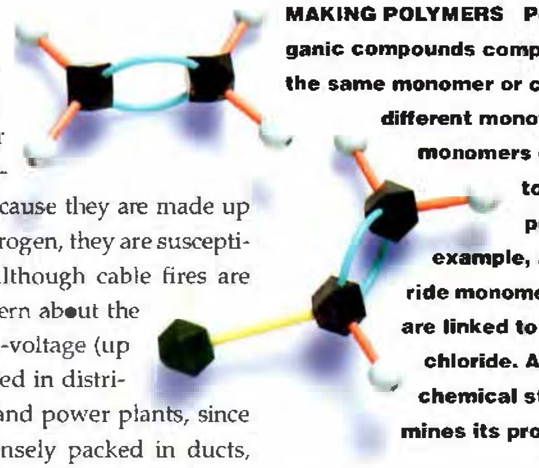
HOT PURSUIT **Flame-retardant materials for cable insulation and jackets must have good mechanical and electrical properties. An EPRI effort has focused on developing improved polymeric formulations for these components.**

Polymers like polyolefins are used in both the exterior jacket and the primary insulation of power cables. Several characteristics make these polymers good for cable applications. Their lack of conductivity minimizes power loss, for example. Also, they are easy to process: many polymer mixtures soften at high temperatures and can be molded, pressed, or extruded into various shapes and sizes before hardening again upon cooling. And their mechanical properties can range from soft and pliable to extremely rigid to meet the requirements of specific applications.

Despite these advantages, pure polyolefin formulations have a distinct drawback for use in flame-resistant insulation: because they are made up of carbon and hydrogen, they are susceptible to burning. Although cable fires are rare, there is concern about the low- and medium-voltage (up to 5 kV) cables used in distribution networks and power plants, since they are often densely packed in ducts, manholes, or cabinets. To reduce the risk of cable fires in potentially flammable areas, flame-retardant substances—typically halogens or nonhalogen metal hydroxides (e.g., aluminum trihydrate)—are added to polymer insulation. These additives provide extremely good flame retardance for cables, enabling them to meet existing specifications, but they do have some shortcomings.

Upon burning, halogenated polymers like polyvinyl chloride release a hydrogen halide gas, which, when combined with antimony oxide, creates a flame-resistant system. Hydrogen halide gases are corrosive, however, and together with the considerable smoke released, they pose safety and toxicity concerns. There is also a danger of corrosion damage to local equipment.

When polymers with aluminum trihydrate burn, they give off water, which serves as a flame quencher. But aluminum trihydrate tends to compromise the mechanical properties of polymer formulations. Because a high loading of the additive is needed for flame retardance, the resulting polymers are relatively stiff and susceptible to cracking, and they can sometimes be snapped apart by strong pulling or damaged by scraping. Also, aluminum trihydrate flame retardant is considered more suitable for cable jackets than for primary insulation because of its potential to conduct current, which can cause the loss of power as heat.

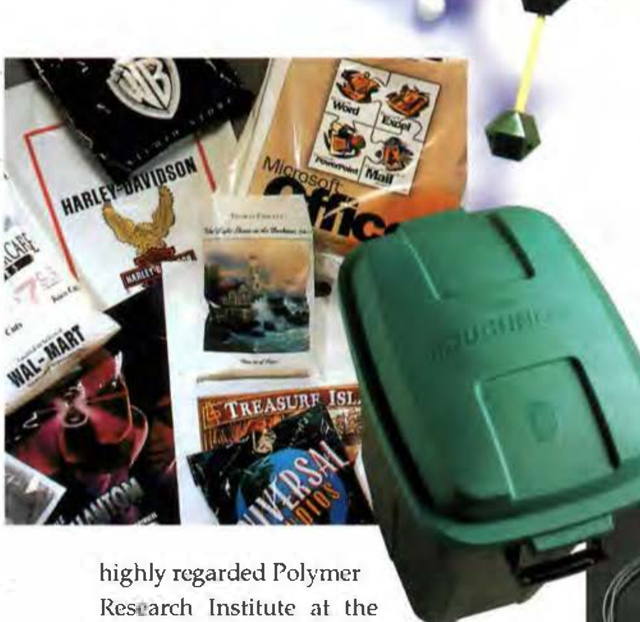


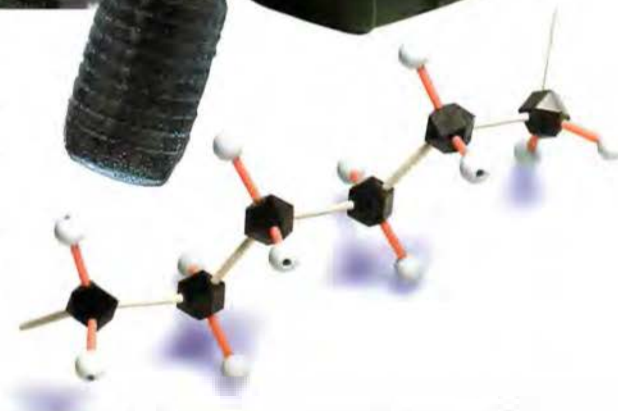
MAKING POLYMERS **Polymers are organic compounds composed of chains of the same monomer or combinations of different monomers. Ethylene monomers (top) are linked together to form polyethylene, for example, and vinyl chloride monomers (bottom) are linked to form polyvinyl chloride. A polymer's chemical structure determines its properties.**

Framing the problem

Since the late 1980s, EPRI has pursued research to identify new uses for polymers and to develop advanced polymers. Polymer formulations are relatively easy to modify by switching additives, adjusting mixing ratios, or introducing new components to produce a material capable of meeting application-specific requirements. But trade-offs are involved: the best formulations have as many favorable characteristics and as few problematic characteristics as possible.

In 1991, to learn more about the latest polymer research activity, EPRI sponsored a visit by Professor Eli Pearce, head of the





VERSATILE MATERIALS
Polyvinyl chloride (left) and polyethylene (right) are two common polymers that, as well as being used in cable insulation, have a host of nonelectrical applications—from packaging materials to fencing.

PHOTOS COURTESY THE VINYL INSTITUTE (FENCES, BOTTLE, MEDICAL SUPPLIES); RUBBERMAID INC. (CONTAINERS); STROUT PLASTICS (PACKAGING)

highly regarded Polymer Research Institute at the Polytechnic Institute of New York. Pearce provided important insights on novel polymer technologies and uses, which inspired Seymour Alpert, a now-retired EPRI Fellow, to consider how emerging polymer technology might be applied to the utility industry's need for good alternative formulations for flame-retardant polymers for power cable insulation.

In realizing the need for new formulations, EPRI had an opportunity to support the utility industry's proactive environmental and safety stance. "Other researchers had been trying to fix the problems associated with the currently used halogen and metal hydroxide additives," recalls Alpert. "We began to ask if there was another way to look at this challenge. What about trying other types of flame-retardant additives to eliminate altogether the undesirable by-products resulting from the combustion of polymer insulation? This approach could perhaps improve on the existing product through a few modifications. But was it feasible to produce new flame-resistant polymer insulation that would have good physical properties, adequate processibility, and reasonable cost and also be environmentally satisfactory?"

Pursuing this line of thought, EPRI's Bruce Bernstein, a polymer specialist, and John Stringer, a materials scientist and technical executive in Strategic R&D, discussed with Pearce the potential for novel approaches to developing flame-retardant polymers. Pearce, in turn, contacted Ed Weil, a New York Polytech professor with a background in industrial chemistry. Weil prepared a research proposal that had the flexibility to be restructured if early concepts did not pay off. EPRI's Exploratory Research group funded the proposal for a three-year period.

"We knew from the outset that Weil had the knowledge, capability, persistence, and equipment to carry the research through to some benefit," says Bernstein. "At the very least, we would gain a great deal of fundamental understanding of the nature of flame retardance in polyolefins. Weil's background as a patent agent also ensured that he would keep the practical aspects of this work well focused."

Although Weil knew where he wanted to be at the end of the research, he had no obvious map to guide him. Bernstein introduced Weil to representatives of Consolidated Edison Company of New York, who helped him identify practical utility needs and practices. Bernstein picked Con Ed not only because it was nearby but also because it was interested in new flame-retardant polymer formulations. Among other things, the utility personnel described the cables used, postfire procedures, and desired improvements. In turn, they learned what could actually be done in a polymer study of this sort.

Weil's first step was to narrow down the many possible avenues of exploration to a reasonable few, which he did by the most effective means—asking other people who might be part way toward a solution or might know something applicable. Weil performed a literature search and surveyed utility and industry personnel about flame-retardant polymer uses and needs.

Industry representatives from a number of organizations—including Akzo Nobel, AT&T, BICC Cables, BP, Du Pont, Monsanto, Southwire, and Union Carbide—gave guidance on polymeric materials used in the field, applicable flame-retardant standards, and test methodologies. For instance, Weil consulted with cable companies and the National Institute of Standards and Technology in selecting realistic laboratory tests for flame retardance. EPRI helped Weil establish some of the industry contacts and provided a sounding board for his ideas throughout the project.

"We weren't performing research in a vacuum. We had direction and we had people to call to ask questions, which results in a very special situation," says Weil. "From utility and manufacturing contacts and marketing information, we had a good feeling for what flame-retardant polymer formulations and ingredients were available, which formulations utilities preferred, and what was needed for the future."

Many suppliers donated flame-retardant chemicals, polymers, and other materials to the project. "Without help from these vendors, the research would have covered a smaller number of materials, and we would have been less likely to find any good combinations that would meet utility needs at low cost and with easy processibility," says Weil. "The suppliers saw this research as an opportunity to develop new applications for their products."

As a result of the extensive coordination with utilities, manufacturers, and suppliers, the project was very focused even though the experiments would cover new ground. Armed with information from these sources and with his knowledge of what other researchers had done on flame-retardant polymers, Weil began forging new paths.

Formulating solutions

Mixtures of polymers and flame retardants were created from the most commonly used ingredients, and their characteristics were tested in the laboratory. When the experimental phase started, a postdoctoral researcher, Weiming Zhu, was recruited from Oklahoma State University

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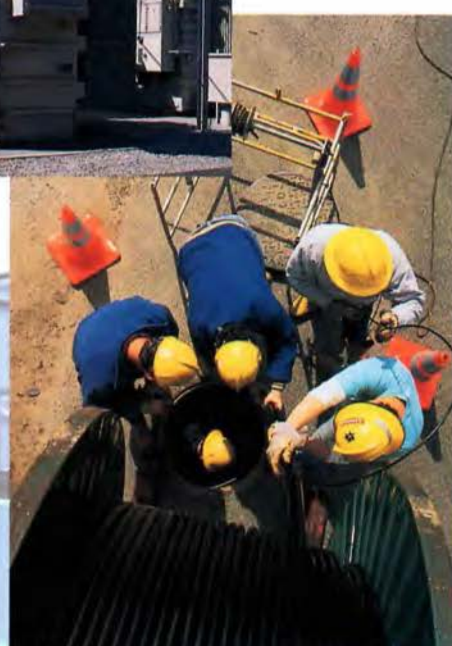
KEY PIECE Melamine, an affordable flame-retardant additive, is an important ingredient of a new polymer formulation for cable insulation.

to produce the mixtures and conduct the laboratory evaluations.

The research initially focused on the addition of catalysts to polymers to eliminate gas evolution and produce a coherent layer of char—material that does not burn completely and thus acts as a flame barrier, blocking combustion of the underlying material. Weil and Zhu studied several combinations



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CLOSE QUARTERS Densely packed low- and medium-voltage cables in such locations as manholes and substations would benefit from enhanced flame-retardant materials.

of polymers, metals, and additional ingredients. They found that the metals did not cause sufficient charring to produce a substantial flame barrier. Catalysts of the originally postulated types were unsuccessful as stand-alone flame retardants; moderate flame retardance resulted only with the addition of a char-forming additive and a clay to the catalyst-polymer mixture.

As a result, Weil and Zhu shifted their focus to noncatalytic formulations. Their goal was to find additives that produced the best limiting oxygen index (LOI) values. (An LOI value indicates the minimum percentage of oxygen that is required for a sample to burn.)

"In research, not everything succeeds as you think it should, but you can usually get good information out of it," notes Alpert. "This work is a prime example of learning and developing further results from amassed knowledge. On the basis of what they had learned from the catalyst experiments, Weil and Zhu were able to start on new formulations that looked quite promising."

The next step was to examine noncatalytic additives that would both absorb heat and produce char, the most effective impediment to further combustion. Various polyolefins and various types and concentrations of additives were tested. Char morphologies were examined to determine which formulations resulted in the most coherent and continuous char production.

After several rounds of trials, Weil and Zhu developed a formulation that provided good flame retardance, promised good processibility, and used affordable additives. The formulation includes melamine, polyphenylene oxide (PPO), and silanated kaolin. Melamine is a common flame-retardant additive used in conjunction with phosphorus compounds for certain coatings and urethane foams. Its heat-absorbing capability appeared to be key to its flame retardance, and the work showed that, contrary to previous belief, a phosphorus co-additive is not needed for melamine to retard flame. PPO, a commercial char-forming polymer from General Electric, had not been used in polyolefins before. Silanated kaolin is an amorphous calcined clay already used extensively in wire and cable insulation because of its favorable insulating characteristics.

"We were very pleased we had created a

promising flame-retardant formulation," says Weil. "We found that the formulation works with several types of polyolefins, which is a definite benefit. And the three compounds necessary for the success of the formulation are all low in cost and suitable for the primary insulation of low-voltage cables."

Next, Weil and Zhu turned their attention to the development of an improved cable jacket that would prevent fire and heat from reaching the primary insulation. Specifically, the goal was to produce a jacket that, when burned, would create copious amounts of intumescent char. Because this kind of char swells considerably when heated, it would provide an extremely effective barrier between fire and the primary insulation. Since the jacket is separated from the cable conductor by the primary insulation, the electrical property demands for the jacket material are not as restrictive as those for the primary insulation.

The melamine formulations in the heat-absorbing experiments did not generate copious amounts of char, and the char was not intumescent, so other ingredients, such as low-water-soluble melamine and various phosphorus flame retardants, were tested. A formulation with good retardance was developed by using melamine phosphate and a phosphonate, a new developmental product from Monsanto.

"It was great to produce a promising formulation for low-voltage primary insulation, but we were very happy to make a formulation for the jacket as well," says Weil. "Being able to build on the information learned in the first part of the project, especially in understanding the benefits of melamine compounds, was a great help. Of course, developing something new is always a slow process, and in this case it will take a lot of additional work to optimize the formulation. Not only do the formulation's mechanical and electrical properties remain to be evaluated, but its processibility is also open to question until it is investigated in full-scale equipment. Aside from the practical outcome, we also made some unexpected observations about the mechanisms of flame retardance, especially about nitrogen-phosphorus synergism and why it occurs."

Toward commercial application

This exploratory research showed that typical polyolefin insulation materials can be made flame retardant with additives that contain neither halogens nor metal hydroxides. The flame-retardant formulation for polyolefins in primary insulation—the formulation based on melamine, PPO, and silanated kaolin—has been patented.

The main results of this work were obtained by testing flat sheets of compounded polymers, but to be useful, insulation material must be extruded over wire. Bernstein asked Weil to see if this was possible, and the researchers succeeded in producing small extruded sections to demonstrate feasibility. For commercial applications, however, very long lengths must be extruded.

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A TOUGH PROBLEM In the lab, many mixtures of flame-retardant compounds and polymers were formulated and tested in order to identify successful candidates for cable applications.

EPRI contacted wire and cable producers to let them know of the new formulation and its properties. Several companies were interested in the formulation, and EPRI licensed it to BICC Cables for further evaluation. The arrangement with BICC is nonexclusive, however, and other organizations are now showing more interest in the formulation. BICC has set up an internal program to evaluate it and to consider going on to the next phase of development.

"Many people from various groups at EPRI helped in taking the patented formulation through the rigorous steps to developing a licensing agreement with BICC," says Bernstein. If preliminary tests are encouraging, further work at BICC would include prototype cable fabrication, mechanical integrity tests, and detailed flammability, smoke, and toxicity tests.

The formulation for cable jacket polyolefins also has been patented and has generated interest from several cable manufacturers. And the insights gained about the mechanisms of flame retardance resulted in the publication of articles in the scientific literature.

Scientific insights and guidelines for future work also emerged from the project. For instance, it was discovered that how fast char accumulates may be even more important for flame retardance than how much char accumulates.

"This work shows how a project goes from exploratory research through the R&D phase and on to technology transfer," says Bernstein. "In this case, the project pioneered a new approach to flame resistance that has been licensed to BICC for further study. This high-risk work, which would never have gotten started via the conventional approval process, has provided an approach that is likely to influence the direction of thinking on flame-retardant polymer technology." The exploratory research path has led to new discoveries of potentially great influence.

"Exploratory research is not just far-out science—its business value can be seen again and again," says EPRI's Stringer. "Products and processes from such research can keep companies profitable and on the cutting edge. Consumers are demanding advanced technology at a faster pace than ever before. One way to meet this demand is to continue work in areas that show promise, knowing that the potential for failure exists. The only certain failure in the long run is not to try." ■

Background information for this article was provided by Bruce Bernstein, Power Delivery, and Seymour Alpert (retired) and John Stringer, Strategic R&D.

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BEYOND SILICON:

Advanced Electr

A graphite-enclosed sample of silicon carbide, a wide-bandgap material, glows in a high-temperature radio-frequency induction furnace.

Power

THE STORY IN BRIEF Large silicon-based electronics are bringing the same control and high-speed switching found in personal computers to utility power control and conversion equipment operating at far higher voltage and current levels. But the packaging and cooling requirements of power electronics make for bulky components. Research is under way to push beyond silicon to so-called wide-bandgap semiconductors. Electronics made from these materials will be lighter and smaller and allow simpler packaging. They also will operate reliably at higher temperatures. Their successful development will open the door to advanced electronics for an expanding array of applications that require high voltage and current capacity and high switching speeds.

by Taylor Moore

Silicon-based, solid-state power electronic devices like thyristors and transistors are increasingly being applied in induction motor drives and utility power transmission and distribution equipment. They allow the same degree of precise control and high-speed switching as the electronics that drive personal computers. In contrast with microelectronics, however, power electronics operate at substantially higher voltage and current levels.

Yet today's power electronics face operating limits that stem from the fundamental nature of silicon-based semiconductors. Most currently available gate-turnoff (GTO) thyristors—the basis for power inverters and other converters used in a growing range of applications—are limited to a blocking voltage of less than 5 kV, a switching speed of 5 kHz, and a maximum operating temperature of 150°C. The devices' associated packaging and cooling requirements result in large, bulky assembled components. And several to many such components are typically required for a complete power electronic system—such as a static synchronous condenser, an EPRI FACTS (Flexible AC Transmission System) technology.

Within a few years, researchers are hoping to push power electronics beyond silicon to so-called wide-bandgap semiconductors like silicon carbide and gallium nitride. Electronic devices made from these materials are expected to be smaller and to feature simpler packaging, for a size reduction of as much as two orders of magnitude from today's power electronics. The new devices will also be commensurately lighter, be more reliable, operate at higher temperatures, and ultimately be less expensive than currently available silicon-based devices. The successful development of such advanced semiconductors will open the door to devices for a wide array of applications that require high voltage and current capabilities and switching speeds at least 10 times greater than possible today but that won't require active cooling.

onics

Just as low-power transistors and integrated circuits made possible the electronics revolution that led to today's modern computer age, it's anticipated that high-power solid-state electronics operating at hundreds of kilowatts or at multimegawatt levels will trigger a second electronics revolution. In this revolution, low-cost, high-power devices and subsystems will become ubiquitous controllers in diverse industrial, automotive, defense, and electricity production and delivery applications. These will include control and propulsion systems for advanced electric and hybrid-electric vehicles for civilian and military use; energy storage, conversion, and interconnection technologies for integrating distributed power sources; advanced power-conditioning electronics for customized distribution and delivery systems; improved, more economical FACTS components; and pulse-power defense technologies, including laser and directed-energy weapons.

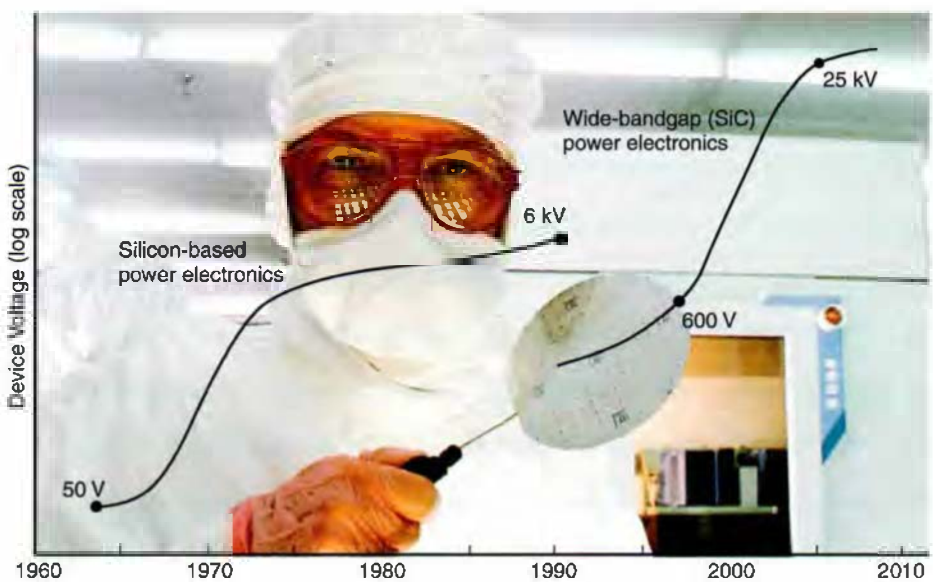
The performance requirements and fabrication challenges for high-power electronics go beyond the capabilities of today's semiconductor manufacturing methods and systems. For that reason, R&D organizations in the two largest potential application sectors—defense and electric power—are jointly pursuing the development of such electronics in a precedent-setting initiative.

Silicon Versus Wide-Bandgap Semiconductors

Property	Silicon	Silicon Carbide	Gallium Nitride
Bandgap (eV at 300 K)	1.1	2.9	3.4
Maximum operating temperature (K)	425	>900	>800
Breakdown voltage (10^6 V/cm)	0.3	4	5
Thermal conductivity (W/cm-°C)	1.5	5	1.3
Process maturity	High	Low	Very low

Wide-bandgap semiconductors like silicon carbide and gallium nitride perform at better than twice the level of silicon.

In January 1997, officials of EPRI and the U.S. Defense Department's Advanced Research Projects Agency (DARPA) agreed to coordinate their research solicitation and funding in order to accelerate the development of high-power devices and circuits that can switch or control dc or ac power levels of 100 kW and above. Since then, about a half dozen multielement R&D activities have been selected for contract awards totaling some $14 million. The projects were chosen and consolidated from 26 team proposals for over $100 million of work that came in response to the initial joint announcement and solicitation. Set to continue through 2001, the EPRI-DARPA initiative combines in a coordinated effort the capabilities of some of the most technologically sophisticated defense electronics contractors, leading electronics manufacturers, and top solid-state physics and electronics researchers at major universities.



RIDING THE WAVE As indicated by these classic S-curves of innovation and market penetration, conventional silicon-based power electronics are approaching fundamental performance limits, while advanced high-power electronics—based on wide-bandgap semiconductors like silicon carbide—are just taking off.

The agreement, signed on behalf of EPRI by Kurt Yeager, president and chief executive officer, notes the common interest of the two organizations in accelerating the development of high-power electronics. This interest stems from the advent of electric and hybrid-electric vehicles—along with related defense developments involving electric propulsion for combat vehicles, aircraft, and ships. In addition, utilities are interested in the R&D because of the dramatic increase in the number and complexity of geographically wide-reaching electric power transactions and transmissions resulting from utility industry deregulation. This trend is driving an increasing need for FACTS technologies that will provide greater control of power flows and will maintain grid reliability.

Both the defense and electric power industries need "the development of high-power, high-speed solid-state switches and other electronic devices to carry out the required control functions and maintain voltage, current, frequency, and other power attributes with minimal energy loss," the agreement states.

For EPRI, the initiative represents an extension of its advanced technology program in high-power electronics, a program whose participants include the Department of Energy, the National Institute of Standards and Technology, the Office of Naval Research, Air Force and Army research organizations, major automotive manufacturers, Harris Semiconductor Corporation, Lockheed Martin Corporation's Northrop Grumman subsidiary, and Silicon Power Corporation. That program and later the joint initiative were spearheaded at EPRI by former Strategic R&D manager Avishay Katz, now a senior technical executive at Watkins-Johnson Corporation.

Electronics for the next century

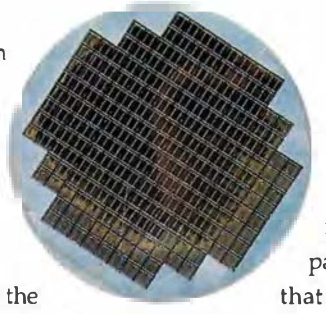
According to Gail McCarthy, EPRI's director of Strategic R&D, the initiative with DARPA is aiming for nothing less than "developing electronic technology for the next century. We're looking to move up the power curve while maintaining and eventually increasing the kind of switching speed obtainable today at lower power levels with silicon devices.

"We're very pleased DARPA has decided to invest in future technology that is beyond its immediate needs and to pursue with EPRI electronics that have very high power levels and switching capacity. If high-power electronic devices were available, companies in the electric power business could use them today. For defense applications, DARPA sees where the technology is headed, and it is willing to invest for the future."

Although EPRI and the Defense Department have cooperated informally in the past on advanced semiconductor R&D, the initiative signals "the first time that we have gotten together in this way, funding multiple projects, both individually and jointly, with a long-term view of what we are hoping to develop," adds McCarthy.

She says that DARPA's interest in the initiative is motivated in part by the broad promise of dual-use civilian and military applications for high-power electronics, most notably applications involving advanced electric propulsion systems. But there are also other functional similarities in applications for defense and utility needs, McCarthy points out. "Modern defense systems involve large, interconnected networks that switch power from a variety of sources but act in an uncoordinated fashion. The reliability of these systems and networks is just as important to the military as power system reliability is to the utility industry."

Terry Ericson, manager of the power electronics program at the Office of Naval Research, offers further perspective on the increasing need for highly reliable electronics. "Because electronic technologies offer unmatched efficiency and flexibility, a good percentage of the high-power systems of the future will be electrical—motors and drives, switches, sensors, even defense systems. Emerging semiconductors provide us with the materials to realize advanced high-power technologies, but only a national effort involving all sectors of the high-power market can deliver the necessary R&D investment."



MOS-controlled thyristor

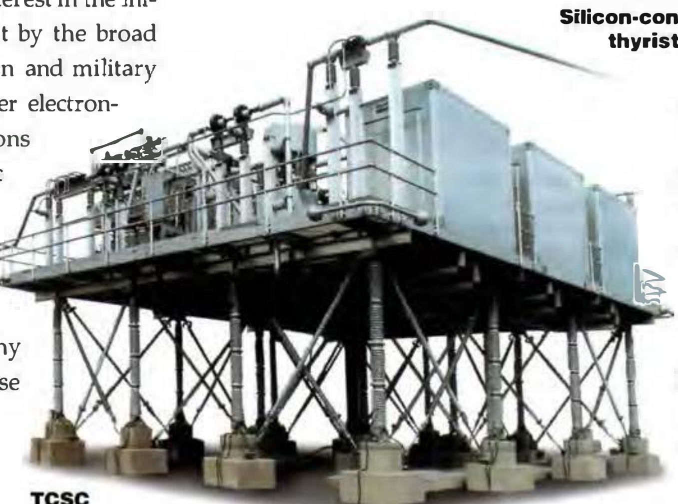
Gate-turnoff thyristor

Silicon-controlled thyristor

Elliott Brown, DARPA's program manager for high power electronics, says that while the technology development challenge is risky, it is "a classic high-risk, high-payoff investment. We think that the megawatt technology is compelling enough for private industry to pick up the development and, we hope, the manufacturing at some point downstream. Our program is aimed at demonstrating this technology in the form of packaged switches within three years and at having an industrial base in fundamental materials and technology development that could produce these components and devices."

Adds Brown, "To us, the involvement of EPRI and the power industry represents the biggest possible market in megawatt solid-state electronics, even bigger than electric vehicles. But the technology for this kind of electronics is too risky for the commercial manufacturers and chipmakers to pursue by themselves. Most of the development in silicon carbide, for example, is occurring in a few small, specialized companies and at defense contractors that are developing very high value-added systems, such as Northrop Grumman for radar.

"The standard commercial vendors that produce power electronics—including such companies as Motorola, International Rectifier, and Harris Semiconductor—are not yet investing heavily in this



TCSC

BUILDING BLOCKS FOR FACTS Today's silicon-based power electronics are typified by high-speed, electronically controlled switching devices like thyristors—fundamental components of EPRI's Flexible AC Transmission System technology for real-time power control. FACTS devices include STATCOM—a static synchronous compensator for voltage support and disturbance damping—and the Thyristor-Controlled Series Capacitor, or TCSC, for transmission line impedance control. High-power electronics based on wide-bandgap semiconductors will make possible lighter, smaller, less expensive FACTS controllers.

STATCOM

area because it is beyond today's technology in terms of fabrication and manufacturing complexity. EPRI and its utility members represent the best path toward establishing the megawatt solid-state electronics market and convincing semiconductor manufacturers to make the investment. We see the agreement with EPRI as a terrific opportunity for commercial market development that will ultimately justify our R&D investment."

Thyristors that can take the heat

DARPA's near-term goal in highpower electronics is to demonstrate and deliver 100-kW inverters within the next four years for tactical systems development. These inverters will be based on fast-turnoff silicon carbide thyristors that can meet the power and switching-speed requirements for emerging hybrid-electric combat vehicles and related power applications.

Thyristors control high-voltage power by switching on and off thousands of times per second. The faster the switching speed and the more voltage they can block, the greater the number of devices into which they can be built and the wider the range of applications they can address.

For DARPA, the goals are temperature-tolerant (300°C) thyristors that can stand off, or block, 5 kV and 200 A of forward current per cell (1000 A per wafer) at a maximum switching speed of 150 kHz, with a forward voltage drop of less than 0.6% of blocking voltage. For utility applications, says Jerry Melcher, who manages power electronics research at EPRI, the ultimate goal is to build a single device or set of devices that can block 25 kV and 2 kA at a switching frequency of 50 kHz and an operating temperature of 250°C.

The power and frequency limits of currently available GTO thyristors stem from limitations inherent in the breakdown voltage, thermal conductivity, and energy bandgap of silicon. (A semiconductor's bandgap is the atomic-level energy required to shift charge carriers from the valence state to the conduction state. Silicon's bandgap is 1.1 electronvolt, or eV.) Because of these limitations, the switches must be thick as well as large in area and must be maintained at a junction temperature of 150°C or lower. These requirements in turn lead to low switching speeds and significant packaging difficulties.

Materials with a wider energy bandgap than silicon—for example, silicon carbide (2.9 eV) and type III nitrides, such as gallium nitride (3.4 eV)—do not have these particular limitations and hence can withstand breakdown voltages greater than three times that of silicon and operating temperatures of over 250°C. But wide-bandgap semiconductors pose other challenges, such as high on-state voltage losses as a result of the lower mobility of charge carriers. "A number of trade-offs are associated with widebandgap materials, and these add up to an enormous set of technical problems," says Melcher. "There are unique challenges involving carrier mobility, doping, contact implantation, and the fabrication of pure parts—parts without crystalline defects at either the microscopic or the atomic level. We're pushing the leading edge of fabricating semiconductors that can operate at high voltage levels."

High-temperature mass spectrometer for materials characterization

PHOTOS BY RON MAY

SRI's radio-frequency induction furnace for heating materials samples or wafers to over 2000°C

SRI International is part of a research team that, under the EPRI-DARPA initiative, is pursuing a broad range of work on wide-bandgap semiconductors, including materials, process, and device development efforts.

Scanning electron microscope display

PHOTOS BY BOB PAZ/CAL TECH

Molecular beam epitaxy machine

Researchers at the California Institute of Technology are coordinating basic research into gallium nitride thyristors and Schottky diodes. They are using advanced epitaxial techniques to control layers at the single-atom level and advanced microscopy techniques to characterize the layers.

Next generation: beyond silicon

The overall focus of the EPRI-DARPA initiative in high-power electronics is on advanced, next-generation devices and basic materials research in wide-bandgap semiconductors. Three of the initiative's funded R&D activities—led by electronics engineers and scientists at the University of Florida, Vanderbilt University, and the California Institute of Technology—focus on the fundamental science of semiconductor materials and devices.

Stephen Pearton at the University of Florida leads a team that includes researchers at Sandia National Laboratories, Lucent Technologies Corporation (which includes the former Bell Laboratories), the Microcomputing Center of North Carolina, SRI International, Germany's Aixtron Semiconductor Technologies, the Swedish Royal Institute of Technology, and Israel's Technion Institute of Technology. This team is investigating materials, process, and device development on a broad front for silicon carbide and gallium nitride in a variety of switching devices.

In another project, Vanderbilt's Leonard Feldman leads a team that includes researchers at Oak Ridge National Laboratory. They are exploring atomic-scale engineering approaches for developing high-performance silicon carbide power devices.

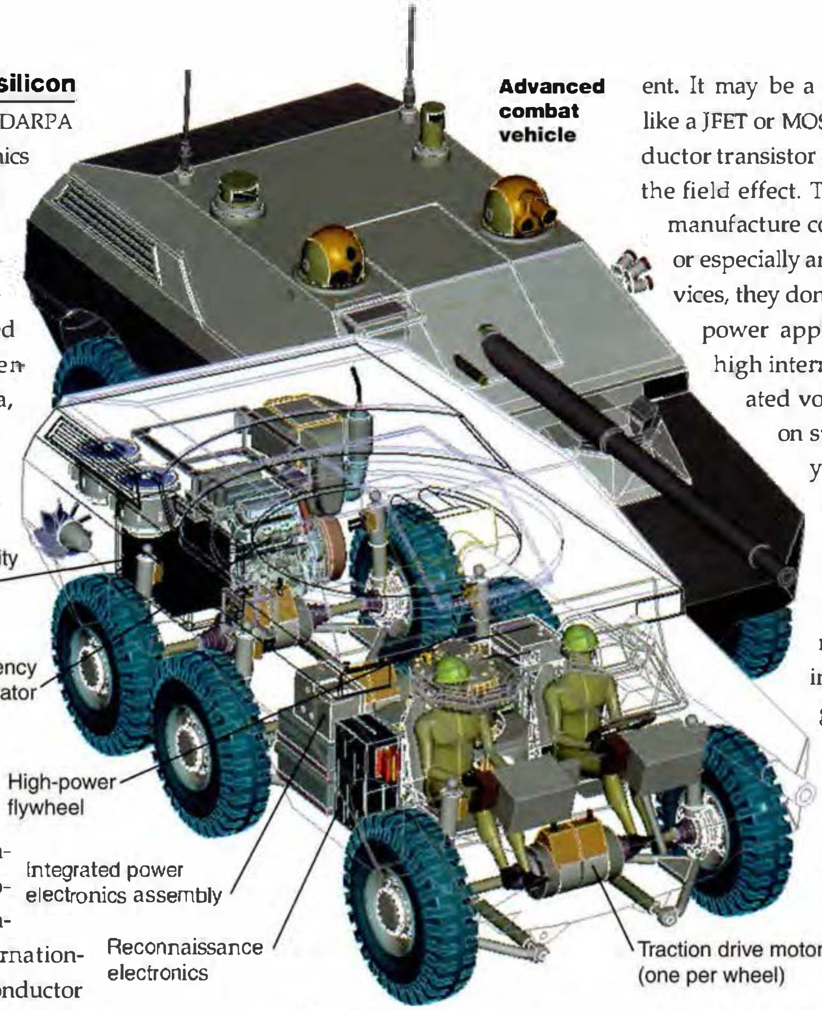
Researchers led by T. C. McGill at Cal Tech, meanwhile, are pursuing basic research into gallium nitride thyristors and Schottky diodes—a type of rectifier that can modify an ac waveform or convert it to dc with very low losses. Schottky diodes are considered by many experts to be the ultimate in power-switching devices.

Commenting on the silicon carbide work, Brown of DARPA points out that the material's advantages over silicon—high-temperature operation, high current density, and high switching speed in a much smaller package—are rather independent of the device involved, whether it's a metal oxide semiconductor (MOS)–controlled thyristor, an insulated-gate bipolar transistor (IGBT), or just a MOS transistor.

"We chose the thyristor as a lead device because it is inherently better for high-voltage, high-power applications," Brown says. "But the ultimate device type for silicon carbide could turn out to be something different. It may be a simple power transistor, like a JFET or MOSFET—standard semiconductor transistor devices that are based on the field effect. They're relatively easy to manufacture compared with a thyristor or especially an IGBT. But like silicon devices, they don't work well in megawatt power applications because of the high internal resistance and associated voltage drop in the switch-on state. With silicon carbide, you could make these devices much smaller, thereby greatly reducing on-state resistance, and take advantage of the material's higher operating temperature and much greater dielectric strength. Silicon carbide devices can switch at power densities approximately 10 times higher than those in silicon devices."

Most of the Defense Department's R&D spending for wide-bandgap semiconductors has focused on silicon carbide because device-grade substrates exist and hence fabrication processes for the material are closer to standard silicon semiconductor fabrication than is the case with, for example, gallium nitride. Still, as EPRI's Melcher and DARPA's Brown both point out, considerable challenges remain in the development of low-defect substrates and high-yield production methods for silicon carbide semiconductors.

"Crystalline silicon carbide is a lot more difficult to grow in bulk form than silicon, with substrate diameters limited to 50 millimeters at this point. In addition, epitaxy is very difficult at the thickness—much greater than 1 micrometer—required for megawatt devices," says Brown. To advance the methods and processes for silicon carbide epitaxy, EPRI and DARPA are cosponsoring a project with NASA at the space agency's Lewis Research Center near Cleveland. A new semiconductor fabrication research facility is being formed at the center to grow improved epitaxial layers for R&D use.



HIGH-POWER DEFENSE **Electric propulsion systems for vehicles, ships, and aircraft are a major focus of defense-related interest in advanced high-power electronics. Also being pursued are power management systems that can control various power sources and energy storage systems and integrate them with propulsion and pulse-power electronic weapons systems. The trend toward integrated electric propulsion and tactical systems is exemplified by an advanced hybrid-electric combat vehicle now under development by DARPA. The vehicle will be able to accommodate a variety of advanced and conventional weapons platforms.**

ARTWORK COURTESY DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

High-power device fabrication

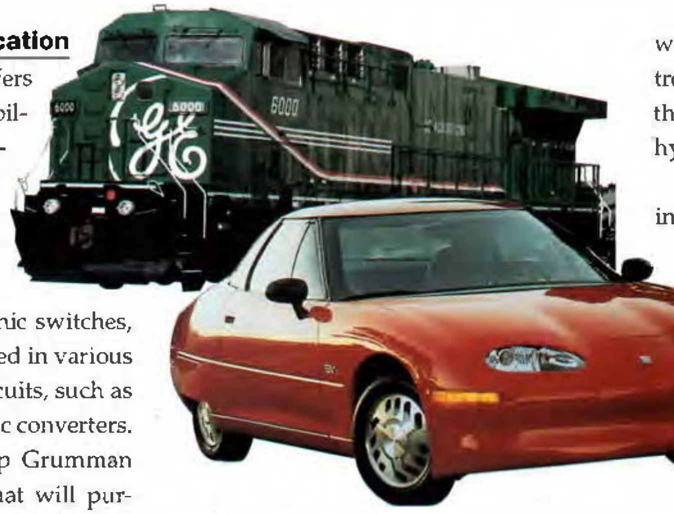
Improved silicon carbide wafers will help accelerate the availability of high-grade epitaxial layers that can be fabricated into multicell semiconductor devices, such as transistors and thyristors. These will form the core of packaged electronic switches, which can in turn be assembled in various ways to form high-power circuits, such as dc-to-ac inverters and dc-to-dc converters.

Researchers from Northrop Grumman are slated to lead a team that will pursue the fabrication of silicon carbide MOS-turnoff (MTO) thyristors and PIN rectifier diodes. Researchers from the Georgia Institute of Technology and Silicon Power Corporation are part of the team. The $4 million DARPA-EPRI jointly funded project will apply all currently available silicon carbide device processing techniques. The goal is to fabricate prototype MTO thyristors that can meet the requirements—5-kV blocking voltage, 1-kA forward current, and 50-kHz switching speed—for use as inverters in hybrid-electric combat vehicles and related power applications. This effort includes the development of advanced fabrication processes and device designs.

Integration into power systems

The successful development of high-power switches and other electronics in the next three to four years under the EPRI-DARPA initiative is expected to directly support DARPA's Combat Hybrid Power System program. The program is aimed at developing an advanced hybrid-electric power system that can provide kilowatts of continuous power for propulsion, computer systems, and the like and gigawatts of stored pulse-power for weapons systems and countermeasures. A 15-ton combat vehicle that incorporates such a power system is being investigated to replace the Bradley Fighting Vehicle.

John Gully, deputy director of DARPA's Tactical Technology Office, says that advanced inverters and other high-power electronics will be needed not just for the diesel- and battery-powered ac induction propulsion motors. They will also be essential for switching, converting, controlling, and managing both continuous loads and pulse-power loads, which likely will require the integration of such advanced energy storage systems as capacitors, ultracapacitors, and flywheels. "The many subsystems envisioned for this future combat vehicle all require electric power, so we must develop a single, integrated power system that can manage all the loads. This is a very different kind of hybrid power system than is being considered for hybrid-electric automobiles and buses."



INDUSTRIAL, CONSUMER APPLICATIONS Like utility and defense applications, many current industrial and consumer applications of power electronics will benefit from the higher power, smaller size, and lower cost of next-generation devices. General Electric's 6000-hp diesel-electric locomotive uses a thyristor-based inverter at each of its traction motors. Thyristor-based inverters are also at the heart of virtually all ac electric vehicle motor drive systems, including that of General Motors' EV1.

TRAIN PHOTO COURTESY GENERAL ELECTRIC TRANSPORTATION SYSTEMS

CAR PHOTO COURTESY GENERAL MOTORS CORP.

Gully says that the opportunity to integrate thermal management of the complex electrical systems planned for the future combat vehicle is a key appeal of the new high-power electronics. "We want a single thermal management system for the combat vehicle that deals with the prime movers, energy storage, and the power electronics. High-power electronics operating at high temperatures are easier to reject heat from than devices operating at lower temperatures. Moreover, they can be installed in hot locations. The Air Force would like to integrate these types of controllers into turbojet engines. We could put them right on the traction motors of the hybrid-electric combat vehicle."

Gully's program is planning a systems integration laboratory to develop and demonstrate a hybrid power system, which initially will be based on silicon semiconductor technology but later will incorporate high-temperature, high-power silicon carbide–based devices. The work will include systems modeling and transient analysis that may even have implications for the analysis of transients on utility power systems, he says.

Strategic benefits for utilities

For utilities and other companies in the business of providing electricity, the arrival of solid-state electronics that are truly high power will improve grid control and energy efficiency for transmission and distribution systems, cost-effectively increasing the utilization of power delivery assets. High-power electronics are also expected to reduce operating and maintenance costs by offering low-maintenance alternatives to wear-prone mechanical switches and systems. Ultimately, the next generation of power electronics will help open up new business opportunities by delivering key enabling technologies for electric vehicles, distributed renewable energy sources, and systems—such as EPRI's Custom Power controllers—for creating value-added electric service options.

"As the cost of power electronics declines, electronic controllers are beginning to be used to improve service for individual distribution system customers," says Karl Stahlkopf, EPRI vice president for power delivery. "When high-power electronic controllers become available, I expect fast market penetration for them because of pressing utility demand and rapid technology development as the industry becomes more competitive in a deregulated market." ■

Background information for this article was provided by Jerry Melcher, Power Delivery.

CONTRIBUTORS

Technical sources for Journal feature articles

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MELCHER

Pricing in Competitive Markets (page 6) was written by science writer Steven Voien with technical information from two members of EPRI's Power Markets & Resource Management (PM&RM) Target.

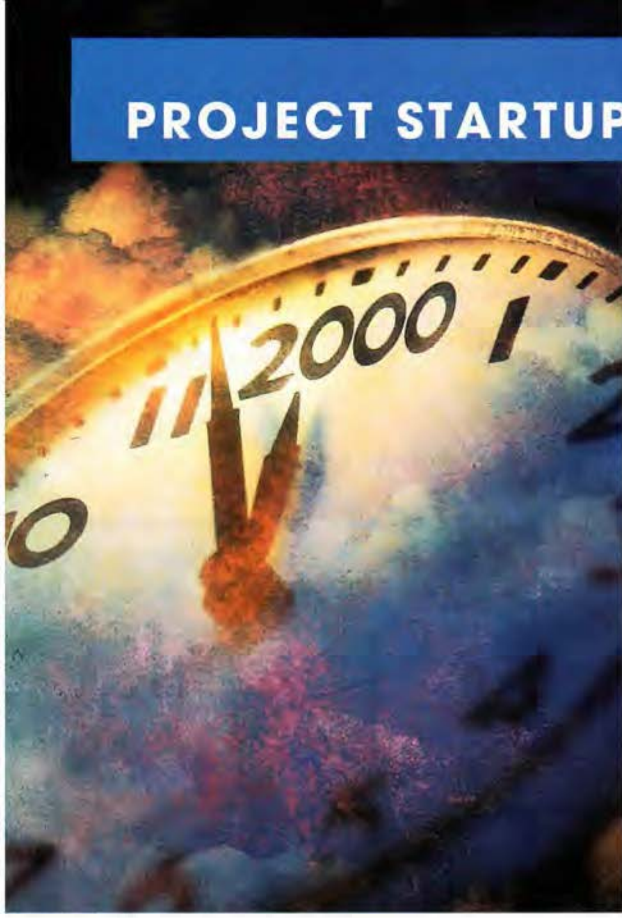
Ahmad Faruqui returned to EPRI this year to head its market management research after over a decade as a consultant to the electric and gas industries, working in the areas of strategic pricing, market demand forecasting, and the design of new products and services. During that period, he held senior consulting positions with EDS, Barakat & Chamberlin, and Battelle and was a principal with Hagler Bailly Consulting. From 1979 to 1986, Faruqui worked at EPRI as a project manager for end-use analysis and forecasting. Earlier he was a consultant to the California Energy Commission in industrial energy forecasting and taught economics at the University of California at Davis. He holds BA and MS degrees in economics from the University of Karachi and a PhD in economics from UC Davis.

Rich Goldberg is currently manager for pricing and risk management, having previously headed PM&RM's risk and asset management work. Before coming to EPRI, he was a senior associate at Decision Focus Incorporated, specializing in electric and gas utility issues, and he has also held research positions at Stanford University, Lawrence Livermore National Laboratory, Princeton University, the National Center for Atmospheric Research, and the Harvard-Smithsonian Center for Astrophysics. Goldberg earned an AB in astrophysical science from Princeton and MS and PhD degrees in physics from Stanford. ■

The New Line on Laundry (page 14) was written by Leslie Lamarre, *Journal* senior feature writer, with technical information from **John Kesselring**, EPRI's manager for residential systems. Kesselring joined EPRI in 1986 after four years as a vice president of Alzeta Corporation. Before that, he was associate manager of the Combustion Technology Department at Acurex Corporation. Still earlier, he was an assistant professor of mechanical and aerospace engineering for five years at the University of Tennessee. Kesselring holds a BS in aeronautical engineering from the University of Michigan and MS and PhD degrees in aeronautics and astronautics from Stanford University. ■

In Search of Fire-Resistant Cables (page 24) was written by science writer Joy Schaber with background information from **Bruce Bernstein**, technical advisor, Power Delivery, who manages work in the area of distribution. Bernstein joined EPRI in 1977 and has served in a variety of positions. Recently he has focused on the polymer insulation problems experienced by electrical equipment of all kinds. He also manages projects on polymer technology for Strategic R&D. Before joining EPRI, Bernstein worked in the wire and cable industry, guiding research on cable materials and aging phenomena as well as fundamental studies of radiation effects on polymers. He holds an MS in organic chemistry from Iowa State University. ■

Beyond Silicon: Advanced Power Electronics (page 30) was written by Taylor Moore, *Journal* senior feature writer, with background information from **Jerry Melcher**, target manager for substations in Power Delivery. Melcher joined EPRI in 1993 after five years as a product manager for Tektronix Corporation. Before that, he was a sales manager at DSP Technology Corporation for four years, and still earlier, he worked at Landis & Gyr Systems. Melcher received a BS in electrical engineering from Worcester Polytechnic Institute. ■



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Embedded Systems and the Year 2000

By now almost everybody in the working world is aware of the year 2000 issue—the possibility that computerized systems may malfunction after midnight on December 31, 1999, because they may not be able to recognize and/or correctly utilize the date 2000.

The problem, which shows up essentially as a date virus, occurs because some of these systems use a two-digit (rather than a four-digit) date format that entirely overlooks the century digits in a date, such as the 20 in the year 2000. As we roll into the new century, there are various ways these systems may interpret the year designation 00. Some software may recognize it as 1900, for example, and some as 2000. How many systems will respond in which way is currently unknown. Embedded microprocessors have internal processing systems that also could recognize 00 as 1900 or 2000 or may even revert to a default value like 1980. Using such wrong dates in arithmetic calculations could result in a range of responses, from no system impact to the complete disabling of a system. The millennium glitch—widely referred to as the Y2K problem—could affect everything from microwave ovens to automobiles and airplanes.

A number of fixes are under development to address the problem in software. But relatively few efforts appear to address the problem in embedded systems—that is, the microcode, firmware, and real-time operating systems that control power plants, distribution systems, and various other industrial equipment and processes. Therefore on October 1, 1997, EPRI—at the request of many concerned power companies—launched a year 2000 project that specifically targets embedded systems.

A kickoff workshop in September drew 165 people from over 50 domestic utilities, 3 international utilities, and a variety of other businesses, including paper manufacturers and petroleum companies. The attendees were vocal in their desire to have EPRI lead a program to consolidate industry information. According to Ric Rudman, EPRI's chief operating officer, "EPRI is moving swiftly to meet these needs because timing on this issue is so critical. Since embedded systems are in use across the entire electricity enterprise, the EPRI program has been set up as a cross-institute and cross-industry effort."

Joe Weiss of EPRI, who is heading up the technical aspects of the fast-track Year 2000 Embedded Systems Project, notes that the efforts of a variety of industries in this country, including many utilities, have been focused almost exclusively on software, especially that for mainframe computers. Yet the cost of addressing the problem in embedded systems is at least as big, he says. "Embedded systems are so widely distributed across this industry that, unless utilities perform analyses, assessments, and mitigation measures, they run the risk of grid problems, power plant trips, and/or reduced power quality."

Participants in EPRI's project will be able to maximize the value of their in-house resources by avoiding duplication of effort and by taking advantage of the positive and negative lessons learned by other participants. The coordinated effort will also ease the burden on dozens of vendors attempting to respond to several hundred utility and other customer requests for similar information.

The diversity of problems, the many vendors involved, and the lack of historical precedents together create an enormous need for information before individual utilities can begin their in-house Y2K compliance programs. According to Charlie Siebenthal, the manager of EPRI's Y2K embedded systems work, "Our program is designed to serve as a focal point for systematically assembling, organizing, sharing, and discussing information that will help participants inventory, assess, and mitigate potential problems. Among the most pressing needs identified by utility Y2K project managers are the development of system and component testing guidelines and the creation of a test result database. An electronic forum through which results can be rapidly disseminated and discussed is also crucial to facilitate the reporting of lessons learned and best practices developed by others."

Owing to the application- and hardware-specific nature of the year 2000 problem, EPRI will not be able to develop generic solutions for use in the industry. Rather, the EPRI program is designed to support the participants' internal Y2K compliance efforts.

The proceedings of the September workshop (TR-109135) are available through the EPRI Distribution Center, (510) 934-4212, and Y2K information is also available online at www.epri.com/y2k.

■ *For more information, contact either Jim Fortune, hfortune@epri.com, (650) 855-2500, or Charlie Siebenthal, csiebent@epri.com, (650) 855-2170.*

Networked Home Links Utilities to Customers

In this digital era, consumers are using an increasing number of electronic devices to improve their lifestyles, accomplish routine tasks, and send information to and from their offices and homes. As residential customers become more comfortable with electronic technologies, equipment and services originally developed for businesses (such as cellular phones, pagers, electronic mail, advanced desktop computers, and fax machines) are becoming more common in the home.

The digital sophistication of the residential market segment comes at a time when the power companies that serve this market are searching for ways to stand apart from their competition. Selling energy management and other value-added services offers a means not only to retain existing customers but also to move into new markets and generate new revenues.

In an effort to integrate the burgeoning residential interest in electronics with the electric utility industry's desire to provide a wide range of value-added services, EPRI has introduced a concept called the networked home. Full of digital technologies that can make life easier and more comfortable for technologically savvy consumers, the networked home is connected to the power company by a two-way communications link. Through this link, utilities can offer customers such services as appliance diagnostics, energy management, and security services.

The initial activities in this effort included a workshop held last February to help launch the networked-home concept and another workshop in November to gather input for 1998.

■ *For more information, contact Steve Drenker, (650) 855-2823.*

New Software Will Address MGP Contamination

Work has begun on a new computer model that will help electric utilities deal with an emerging issue associated with former manufactured gas plant (MGP) sites: contaminated sediments in surface water.

EPRI's Model for the Assessment and Remediation of Sediments (MARS) will provide a flexible tool for characterizing the transport and fate of various chemicals in aquatic environments, evaluating risks associated with sediment contamination, and comparing remediation alternatives.

Regulatory interest in contaminated sediments is growing, and the more than 1500 former MGP sites nationwide pose a significant management challenge for utilities. Developing an understanding of sediment-water interactions and of possible aquatic ecosystem impacts is critical to remediation decisions. The MARS software will integrate existing hydrodynamic, sediment transport, chemical fate and transport, and bioaccumulation modules to study sediment-bound MGP compounds, including volatile organic chemicals (such as benzene, toluene, ethylbenzene, and xylene) and polycyclic aromatic hydrocarbons (such as naphthalene, phenanthrene, and chrysene).

At this time, researchers have conceptualized the software's components, and programming has begun. The hydrodynamic module will simulate the movement of water in a river to help determine rates of sediment settling and suspension and to identify areas of erosion and deposition. The sediment transport module will use results from the hydrodynamic module to calculate how contaminated sediments are transported and deposited. The chemical fate and transport module will describe the adsorption and desorption of individual chemicals between layers of sediment and the overlying water. Results from these three modules will be used by the bioaccumulation module to model uptake, metabolism, and accumulation in invertebrates, small fish, and predatory fish.

MARS will make it possible to assess alternative remediation scenarios in terms of how they affect the physical system and hydraulics, water and sediment quality, and resident biota. Users will be able to run only the portions of the model needed for the task at hand and to investigate treatment options by changing simulation variables as desired. MARS will address in situ remediation technologies—for example, armoring, natural recovery, enhanced sedimentation, and bioremediation—as well as removal options like dredging. The first version of the program is expected within two years.

■ *For more information, contact Ashok Jain, (908) 253-8909.*

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.

CUSTOMER SYSTEMS

Wireless Product Applications for Utilities
TR-106352, Final Report
EPRI Project Manager: R. Skelton

Leveraging Utility Assets in Wireless Communications
TR-106382, Final Report
EPRI Project Manager: R. Skelton

Commercial Kitchen Ventilation Performance Report: Two Electric Pressure Fryers Under Wall-Mounted Canopy Hood
TR-106493-V11, Final Report
EPRI Project Manager: W. Krill

Commercial Kitchen Ventilation Performance Report: Six-Burner Gas Range Top Under Wall-Mounted Canopy Hood
TR-106493-V12, Final Report
EPRI Project Manager: W. Krill

Application Program Interfaces (APIs) Issues for Nomadic Wireless Communications
TR-107127, Final Report
EPRI Project Manager: R. Skelton

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EPRI Project Manager: J. Kesselring

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TR-108523, Proceedings
EPRI Project Manager: P. Meagher

The Harmonic Impact of Electric Vehicle Battery Charging
TR-108540, Final Report
EPRI Project Manager: B. Banerjee

Test of a 4-kW Doubly Salient Permanent-Magnet Motor Drive
TR-108763, Final Report
EPRI Project Manager: B. Banerjee

Advanced Billing and Customer Specification Requirements
TR-108895, Final Report
EPRI Project Manager: D. Cain

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TR-108918-V1, Final Report
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National Electric Vehicle Infrastructure Working Council: Committee Meeting Minutes #97-2
TR-108925, Final Report
EPRI Project Manager: L. Sandell

ENVIRONMENT

Leukemia/Lymphoma in Mice Exposed to 60-Hz Magnetic Fields: Preliminary Studies and Protocol
TR-108064, Interim Report
Contractors: University of California, Los Angeles; Basic and Clinical Research and Education Association, Inc.
EPRI Project Manager: C. Rafferty

Evaluation of Occupational Magnetic Field Exposure Guidelines
TR-108113, Interim Report
Contractor: T. Dan Bracken, Inc.
EPRI Project Manager: R. Kavet

Technology Review: Treatment of Complexed Cyanide in Water
TR-108596, Final Report
Contractor: Carnegie Mellon University
EPRI Project Manager: I. Murarka

An Analysis of Cost Savings for a Constructed-Wetland Treatment System
TR-108652, Final Report
Contractor: EES Consultants, Inc.
EPRI Project Manager: J. Goodrich-Mahoney

Susceptibility of Implanted Pacemakers and Defibrillators to Interference by Power-Frequency Electric and Magnetic Fields
TR-108893, Final Report
Contractor: A. S. Consulting & Research, Inc.
EPRI Project Manager: R. Kavet

GENERATION

Evaluation of Heat Rate Discrepancy From Continuous Emission Monitoring Systems
TR-108110, Final Report
Contractors: RMB Consulting & Research, Inc.; Fossil Energy Research Corp.
EPRI Project Manager: C. Dene

Santa Clara 2-MW Fuel Cell Demonstration: Power Plant Test Report
TR-108252, Final Report
Contractor: Fuel Cell Engineering Corp.
EPRI Project Managers: T. O'Shea, D. Rastler

Microturbine Generator Test at Northern States Power Company
TR-108297, Final Report
Contractor: Northern States Power Co.
EPRI Project Manager: D. Herman

Infiltration Processing of Metal Matrix–Fly Ash Particle Composites
TR-108531, Interim Report
Contractors: University of Wisconsin, Milwaukee; Wisconsin Electric Power Co. (cosponsor)
EPRI Project Manager: D. Golden

Analysis of a Photovoltaic System Located on the Union of Concerned Scientists' Cambridge Office
TR-108978, Final Report
Contractor: Union of Concerned Scientists
EPRI Project Manager: F. Goodman

NUCLEAR POWER

Examination of Kewaunee Steam Generator Sleeves With Hybrid Expansion Joints
TR-105905, Final Report
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: A. McIlree

Permanent Lead Shielding for Nuclear Safety Piping Systems
TR-105995, Final Report
Contractor: Sargent & Lundy Engineers
EPRI Project Manager: H. Tang

Multipurpose Canister System Design Synopsis Report: Summary of the DOE System for Storage, Transportation, and Disposal of Spent Nuclear Fuel
TR-106962, Final Report
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: O. Ozer

B&W Advanced Control System (ACS) Information Archive
TR-107942-CD, Final Report
Contractor: DVP Techdoc
EPRI Project Manager: R. Torok

Soil-Structure Interaction of the Lotung Quarter-Scale Structure: Sensitivity Studies
TR-108854, Final Report
Contractor: EQE International, Inc.
EPRI Project Manager: H. Tang

POWER DELIVERY

A Unified Index for Stability Assessment and Enhancement
TR-108358, Final Report
Contractor: Howard University
EPRI Project Manager: R. Adapa

Aging Study of Distribution Cables at Ambient Temperatures With Surges
TR-108405-V1, Final Report
Contractor: Cable Technology Laboratories
EPRI Project Manager: B. Bernstein

Aging of Distribution Cables in Controlled-Temperature Tank Tests
TR-108405-V2, Final Report
Contractor: BICC Cables Co.
EPRI Project Manager: B. Bernstein

Performance-Based Monitoring and Control of Transformers
TR-108406, Final Report
Contractor: Massachusetts Institute of Technology
EPRI Project Manager: R. Adapa

Proceedings: Tenth Electric Utility Forecasting Symposium—Forecasting in an Era of Deregulation
TR-108523 (see listing under Customer Systems)

STRATEGIC R&D

Electroseparations: A Survey in Energy Assessment
TR-107795, Final Report
Contractor: Oak Ridge National Laboratory
EPRI Project Manager: A. Amarnath

Possible Effects of Chlorine Content of Coal on Fireside Corrosion in Pulverized Coal-Fired Boilers, Vols. 1–3
TR-108107, Final Report
Contractors: Oak Ridge National Laboratory; PowerGen PLC
EPRI Project Manager: A. Mehta

Photoinhibition of Localized Corrosion (Phase 2)
TR-108563, Final Report
Contractor: Pennsylvania State University Center for Advanced Materials
EPRI Project Manager: B. Syrett

EPRI Events

DECEMBER

1–3
Getting Started on Life-Cycle Management of Nuclear Power Plants
St. Pete Beach, Florida
Contact: Brent Lancaster, (704) 547-6041

2–4
Transmission Inspection and Maintenance Training
Las Vegas, Nevada
Contact: Kathleen Lyons, (650) 855-2656

8–9
Generator Retaining Ring Workshop
Miami, Florida
Contact: Michele Samoulides, (650) 855-2127

8–11
CHEC-T Users Group
Reno, Nevada
Contact: Megan Boyd, (650) 855-7919

8–11
EPRI/NMAC Pump Maintenance Workshop
Charlotte, North Carolina
Contact: Linda Suddreth, (704) 547-6141

8–12
Drum-Type Coal-Fired Steam Plant Operations
Kansas City, Missouri
Contact: Sarah Vanberg, (816) 235-5623

9–10
Insulator-Aging Workshop
Palo Alto, California
Contact: Bruce Bernstein, (202) 293-7511

9–10
Reliability-Centered-Maintenance Training
Orlando, Florida
Contact: Predrag Vujovic, (650) 855-2991

9–12
Nuclear Utility Procurement Training Course
Charlotte, North Carolina
Contact: Brent Lancaster, (704) 547-6041

10–11
Ancillary Services Workshop
Miami, Florida
Contact: Cindy Layman, (650) 855-8763

10–11
1997 EPRI-DOE Wind Turbine Verification Program
Tehachapi, California
Contact: Peggy Amann, (650) 855-2259

10–12
International Conference on Instrumentation and Control Issues in Nuclear Power Plants
St. Petersburg, Florida
Contact: Melita Guellert, (650) 855-2010

15–17
14th International Electric Vehicle Symposium
Orlando, Florida
Contact: Mary Nakama, (650) 855-2621

15–17
ISI/IST Workshop
Corpus Christi, Texas
Contact: Sherryl Stogner, (704) 547-6174

JANUARY 1998

4–7
Enhancing Business Opportunities Through International Collaboration
Orlando, Florida
Contact: Eileen Mauro, (614) 421-3440

13–16
Relays Component Working Group Meeting
Charlotte, North Carolina
Contact: Brent Lancaster, (704) 547-6041

14–15
Distributech
Tampa, Florida
Contact: Ann Iverson, (650) 855-1062

14–15
NMAC Freeze Sealing Workshop
Charlotte, North Carolina
Contact: Linda Suddreth, (704) 547-6141

14–16
NMAC Pressure Relief Devices Users Group
Orlando, Florida
Contact: Linda Suddreth, (704) 547-6141

16–17
A Consortium for the Application of Climate Impact Assessments: Executive Board Meeting
Phoenix, Arizona
Contact: Chuck Hakkarinen, (650) 855-2592

21–23
International Poultry Exposition
Atlanta, Georgia
Contact: Barry Homler, (419) 534-3713

27
6th CMP Symposium on Electric Arc Furnace Dust Treatment
Pittsburgh, Pennsylvania
Contact: Joe Goodwill, (412) 268-3435

28
MANAGES Database Training
Albuquerque, New Mexico
Contact: Adda Quinn, (650) 855-2478

28–30
PM2.5: A Fine-Particulate Standard
Long Beach, California
Contact: Pradeep Saxena, (650) 855-2591

29
MOSES-MP Software Training
Albuquerque, New Mexico
Contact: Adda Quinn, (650) 855-2478

FEBRUARY

9–13
Heat Exchanger and Condenser Component Working Group
Charlotte, North Carolina
Contact: Brent Lancaster, (704) 547-6041

16–18
6th Substation Equipment Diagnostics Conference
New Orleans, Louisiana
Contact: Michele Samoulides, (650) 855-2127

17–20
Magne-Blast Circuit Breaker Users Group
Orlando, Florida
Contact: Brent Lancaster, (704) 547-6041

18–20
Water and Energy Conference
San Antonio, Texas
Contact: Kim Shilling, (314) 935-8590

25–27
ProfitManager Training and Users Workshop
Palo Alto, California
Contact: Lynn Stone, (972) 556-6529

MARCH

4–5
Globalcom
Dallas, Texas
Contact: Orin Zimmerman, (650) 855-2551

12–13
EPRI Partnership for Industrial Competitiveness
San Diego, California
Contact: Bill Smith, (650) 855-2415

16–19
8th International Conference on Zebra Mussels and Aquatic Nuisance Species
Sacramento, California
Contact: John Tsou, (650) 855-2220

16–19
Transmission and Distribution Underground Construction Workshop
Las Vegas, Nevada
Contact: Kathleen Lyons, (650) 855-2656

17–20
Feedwater Pump Turbine Component Working Group
Charlotte, North Carolina
Contact: Brent Lancaster, (704) 547-6041

24–25
HELM Users Meeting
Seattle, Washington
Contact: Paige Schaefer, (800) 398-0081

26–27
REEPS/COMMEND/INFORM Users Meeting
Seattle, Washington
Contact: Paige Schaefer, (800) 398-0081

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