Wrestling With National Energy Policy

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Also in this issue • Nuclear Risk Assessment • EPRINET • Cold Fusion Update

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Cover: Ensuring an adequate, affordable supply of oil is one of several critical issues in U.S. energy policy. The United States currently relies on imports for about half the oil it consumes.

EDITORIAL

Beyond Crisis Management

While a favorable outcome in the Persian Gulf war may significantly improve prospects for Middle East oil availability, we must not fool ourselves into thinking this would solve all our energy problems. Crisis management has never been—and will never be—a real energy strategy. Our horizon in energy policy should be decades, not years, given the long life cycles and capital-intensive nature of our energy supply infrastructure.

An effective strategy not only must ensure a steady supply of energy but must also thoughtfully reconcile economic and environmental aspirations with our resource realities. It should have at its core improving efficiency in every way we can—during energy production, delivery, and use. To the same end, we must deal more strategically with our capital and environmental investments. While electricity's cleanliness and versatility make it in many ways the ideal energy form for the future, these advantages at the point of use have merit only if we deal more holistically with environmental issues at the generating station.

We must solve our oil problem! Oil represents 42% of U.S. energy consumption, almost twice the share of coal or gas. The 54% of that oil that is imported accounts for about half of the U.S. trade deficit. And while utility use of oil has declined substantially over the last two decades, automobile emissions continue to produce the most intractable of our environmental problems—urban pollution.

For electricity generation today, natural gas is clearly the premier fuel. Its cost, cleanliness, and compatibility with high-efficiency combustion turbine–combined-cycle systems make it the optimal short-term option for new supply and the repowering of older units. Our ability to fuel these systems with gasified coal in the future provides an ideal hedge against a decline in natural gas resources. Our mid- to long-term priorities must focus on coal, nuclear, and solar power—in both the R&D and the public arena. The best hope for our energy future is to turn technology and the human intellect—truly renewable resources—to adapt these energy options to our societal requirements.

We should not lose sight of the versatility of electricity in the home and the workplace and its ability to improve our economic productivity through innovative electrotechnologies. Electrification has been a critical ingredient of this nation's significant improvement in overall energy efficiency over the last century. I believe it represents the cornerstone of a rational long-term energy strategy for the nation and for the world—a strategy that will permit societies to leverage their energy consumption for greater productivity, to further diversify resources to non–fossil fuel options, and to meet humankind's need for energy within an environmentally sustainable framework.

Richard E. Balzhiser
President and Chief Executive Officer

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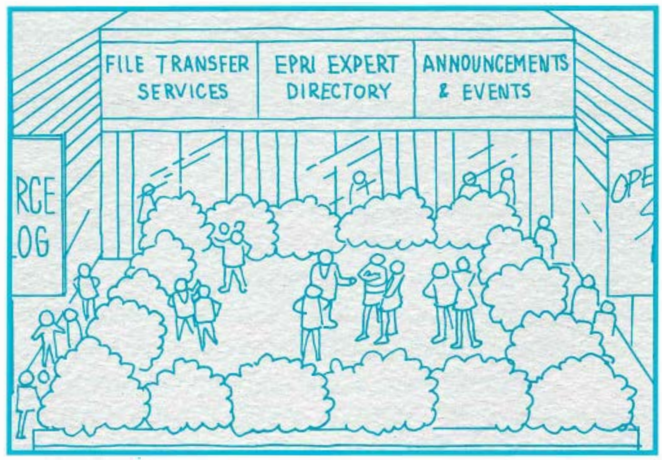

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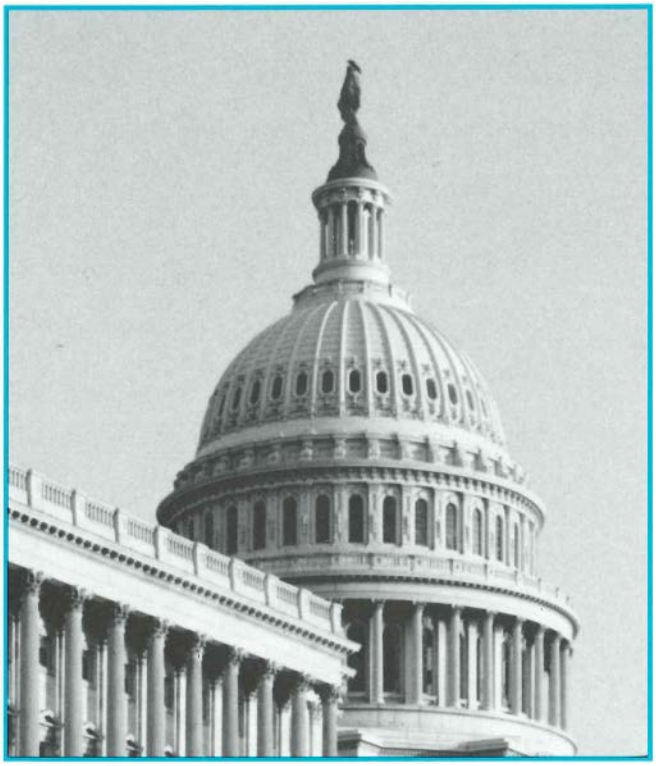
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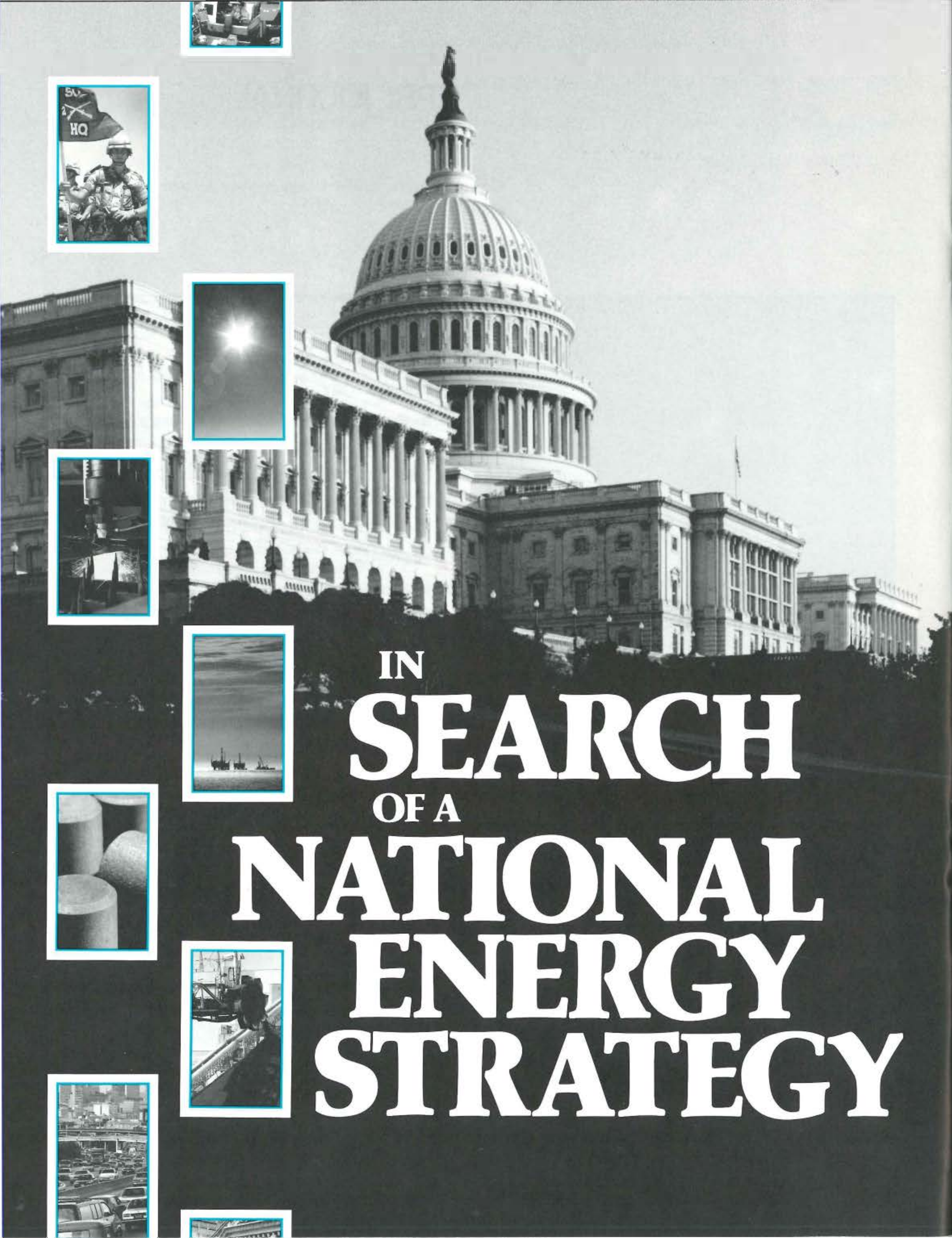


IN SEARCH OF A NATIONAL ENERGY STRATEGY

More than a year before Iraqi tanks rumbled into Kuwait and triggered an oil price shock that evokes memories of energy crises of the past, the United States government set out yet again to develop an energy strategy for the nation. The current crisis in the Persian Gulf, rooted in the Western world's heavy reliance on oil for energy (the largest reserves of which lie beneath the Middle East), in many ways overshadows—and could in the short run overwhelm—many of the policy developments now coming together under the heading of energy strategy. Yet each day's events in the gulf also bring into sharper relief and urgency the broader, perennial, and often more subtle and difficult problems of energy that have been recognized for several decades.

The government has had what were, in effect, energy policies since at least the 1920s, when it tried to encourage the production of then-scarce liquid fuels from oil shale before the discovery of the great East Texas oil fields late in the decade. The goal initially was to ensure an adequate and affordable supply of feedstock for making kerosene. But with the advent of that most liberating and economically profound of American products—the automobile—and the oil gushers of the 1920s in Texas and Oklahoma that ushered in the era of cheap oil, transportation in its various forms and the consequent demand for petroleum-derived fuels have been at the heart of U.S. energy economics, policy, and politics.

As has been demonstrated in the past as well as during the most recent crisis in the Persian Gulf, generally it is only in response to the threat of a crisis—real or imagined—that most Americans pay much attention to energy matters or show much support for energy policies. These policies continue today to center, in large part, on ensuring adequate, affordable supplies of oil and other forms of energy. But now they must also be

THE STORY IN BRIEF

In mid-1989, President Bush charged DOE with the development of a new National Energy Strategy, the need for which has since been highlighted dramatically by the crisis in the Persian Gulf. Yet most of the concerns and issues in energy policy have been with us for many years. Today, in addition to the matter of the security of Middle East oil supplies, the environmental costs of energy and the effects of energy prices on global economic development and productivity cast issues of national energy policy in the broadest possible, global context. As the government wrestles with the tough trade-offs involved in putting a comprehensive plan together, senior energy experts from within EPRI and the ranks of its advisers provide telling observations and perspective on the history of U.S. energy policy, the barriers to formulating a lasting strategy, and the imperatives for the nation's energy future.

consistent with other important policy goals, such as environmental protection and the overall health of the economy.

The importation of oil from foreign sources has been viewed with varying degrees of alarm in this country since the earliest days of the discovery of large domestic supplies. At first, the threat was perceived solely as an economic one. A tariff was imposed on lower-cost imports to protect domestic producers soon after the East Texas strikes.

An anticipated shortage of petroleum for fueling projected industrial expansion after World War II led to federal policies and projects (similar to those of the 1920s) to produce synthetic liquid fuel from coal and from natural gas—then a largely wasted by-product of oil production. Several large demonstration plants, mainly based on technologies developed and used by Germany during the war, were built and operated by the government and the oil and chemical industries.

But efforts to realize the synthetic routes to transportation fuel were abandoned in the 1950s, when low-cost petroleum from the Middle East made them economically uncompetitive. During the Eisenhower administration, quotas limited the volume of imports after the first flood of oil onto world markets began from Iran.

Meanwhile, beginning in the late 1940s and continuing into the 1970s, most energy experts and government policymakers saw the emerging technology for nuclear power generation as the energy source of the future. Along with the use of available hydroelectric resources, nuclear power was from the beginning viewed as the development path for an eventual transition away from oil and other fossil fuels.

But it was not until the first real oil price shock, a result of the Arab embargo stemming from the 1973 Yom Kippur War in the Middle East, that the United States explicitly recognized energy as a national security issue and, specifically, oil imports from unstable parts of the world as a potential threat to national security. Congress enacted a system of price controls and supply rationing of oil that experts now agree was the cause of subsequent shortages and consumer lines at gasoline stations. In addition to administering the price controls, the Nixon administration crafted a longer-term energy policy centered around the greatly expanded use of nuclear power. Dubbed Project Independence, the policy had as its goal achieving national energy self-sufficiency by 1985.

Part of the government's response to the first oil shock was to establish a strategic reserve of oil, stored in underground salt domes in Louisiana for use in emergencies. But throughout most of the 1970s, a rising tide of oil imports continued. Little changed from the days of Project Independence to the time of the next big shock in oil prices—as a result of the 1979 Islamic revolution in Iran. There was a new president, however, as well as a new Department of Energy (DOE), whose creation brought most federal energy-related programs under a cabinet-level agency for the first time.

President Carter, televised wearing a sweater and urging viewers to turn down their thermostats, called on Americans to exert the "moral equivalent of war" to conserve energy and to develop alternative fuels and renewable resources. He called nuclear power an option of last resort because of the potential to spread technology for nuclear weapons. The major expansion of nuclear power anticipated as recently as a few years earlier failed to materialize, as utilities canceled plant orders in the face of steeply rising costs and regulatory requirements, a slowing demand for electricity, and often hostile public opinion.

Carter and the Congress launched a massive federal subsidy program called the Synthetic Fuels Corporation that was designed to bring all sorts of alternative fuels into production. With echoes of the pioneering shale oil projects the government had encouraged half a century earlier, numerous plants were built by industry with government loans and guarantees under the synfuels program to convert coal, shale, and natural gas into clean fuels. While only a few of the plants remain in operation, the technological advances made have put several successful processes in a strong position for future commercial deployment, but at costs significantly higher than even the post–Kuwait invasion oil prices.

During the 1980s, President Reagan reversed much of the activist role of the federal government in energy matters, saying that less regulation and a greater reliance on market forces constituted the best energy policy. He completed the decontrol of oil and gas prices begun under Carter, reined in and wound down the Synthetic Fuels Corporation, and sharply reduced federal energy R&D budgets. According to some, his administration discounted a need to encourage energy conservation, preferring incentives to spur increased energy supplies.

Reagan was in office when, in late 1985, slowing world demand for oil and rising production from countries that were not part of the Organization of Petroleum Exporting Countries (OPEC) caused prices to collapse by more than 50%. Through the latter half of the decade, the trends of increasing energy efficiency—spurred by higher oil prices since 1979—slowed in several sectors of the economy. Americans again began to buy larger, more powerful, and less fuel-efficient vehicles.

But while low oil prices in the late 1980s meant a break for consumers and the economy, they spelled disaster for much of the domestic oil industry. Drilling dwindled and many wells shut down for good when prices no longer sustained their production cost. The share of U.S. oil consumption supplied by imports, which had retreated from the mid-40s percentage levels of the late 1970s to the upper 20s in the mid-1980s, climbed back up after prices fell and was

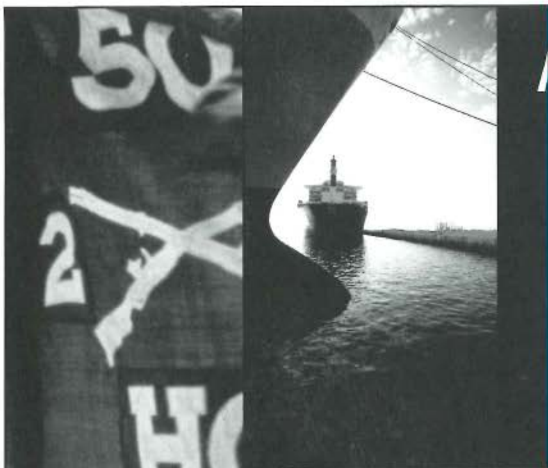


Photo by Piergiorgio Sclarandis/Black Star

An expensive dependence About 60% of the world's estimated 800 billion barrels of proven and indicated oil reserves lie beneath the Middle East. In 1989, before the gulf crisis, the United States spent nearly $45 billion on imported oil. Today the tab has climbed to over $50 billion a year, accounting for about half of the country's foreign trade deficit.

Photo by J. Langevin/Sygma

expected to top 50% by the end of last year.

Although there was criticism that the Reagan administration had no energy policy, a 1987 DOE study in fact warned yet again that rising dependence on oil imports posed a threat to national security; it urged expansion of domestic production of oil and gas as well as other energy forms, plus conservation. Critics continued to fault the administration, however, for not offering a comprehensive, long-term energy strategy with sufficient R&D support. The debates on energy issues that did occur divided along partisan political lines.

But neither the public nor the policymakers were ignoring the deepening sensitivity to environmental values that began to take hold in the 1970s. The fact that all energy sources pose environmentally undesirable by-products or risks, and that the costs of most of these are not reflected in the market price of energy, became increasingly accepted by both supply-siders and demand-siders in energy debates.

Environmental values have come to be regarded politically as having the same importance as energy security and economic productivity. Last year, Congress —with presidential support—enacted a major update of the Clear Air Act after more than a decade of debate, imposing stiff new environmental limits and added costs throughout the energy-using economy. Moreover, a growing number of Americans are aware that the specter of global climate change, presumably accelerated by the world's use of fossil fuels, could eventually become the dominant environmental concern—a concern that threatens to limit energy and economic development and cause new tension between developed and less-developed countries.

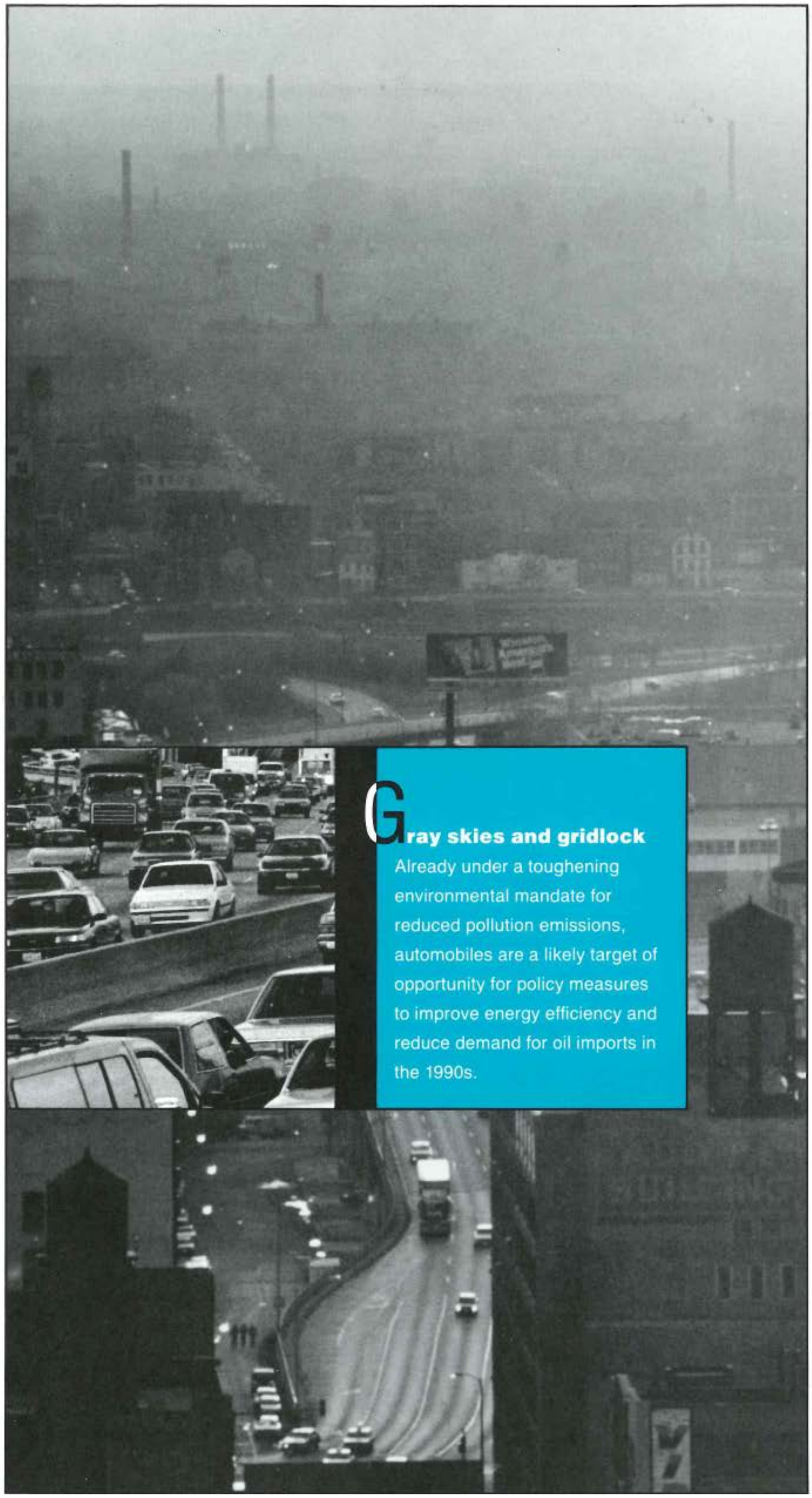
A new charter to seek national consensus

In July 1989, midway into the first year of his administration, President Bush directed DOE to begin development of a new National Energy Strategy, declaring that "we cannot and will not wait for the next energy crisis to force us to respond." The president said he wanted the strategy to be built on a national consensus and to be "responsive to new knowledge and new ideas, and to global, environmental, and international changes."

In his charge to DOE, the president said the policy must continue to rely on market forces yet must balance the nation's increasing need for energy at reasonable prices with a commitment to improving the environment, maintaining economic competitiveness, and reducing dependence on potentially unreliable energy suppliers.

In the following months, DOE gathered extensive public and technical input in a series of 18 public hearings around the country. Over 22,000 pages of written submissions were made by various individuals, industries, and institutions. EPRI participated in the process, submitting a report that outlined the strategic role electricity could play in balancing concerns for energy efficiency, adequate supplies, and environmental objectives. Several members of EPRI's technical staff provided testimony at regional DOE hearings. President and CEO Richard Balzhiser testified on behalf of the collaborative development effort under way in electric vehicles, stating the case for the contribution EVs could make in diversifying transportation energy options while directly contributing to reduced pollution emissions.

The complexities and difficult challenges of shaping a comprehensive energy strategy that can spur and guide legislative, political, regulatory, and lifestyle changes in energy matters are readily apparent. Many of the trade-offs embodied in such a strategy involve balancing short-term objectives with longer-term goals. DOE has said the strategy will identify short-, mid-, and long-term options within a horizon that extends to 2030.



Gray skies and gridlock
Already under a toughening environmental mandate for reduced pollution emissions, automobiles are a likely target of opportunity for policy measures to improve energy efficiency and reduce demand for oil imports in the 1990s.

A major preoccupation for the department while in the midst of work on the strategy was the fallout from Iraq's invasion of Kuwait and the United Nations boycott of oil from both countries; the boycott immediately removed over 4 million barrels a day from the world market, including 700,000 barrels coming to this country. (The United States consumes more than 17 million barrels of oil a day, or over 6 billion barrels a year.) Soon after the crisis developed, DOE urged Americans to fully inflate vehicle tires for better mileage and to buy lower-octane gasoline. The administration proposed new tax credits to spur domestic oil exploration and new procedures to speed up permit processing for natural gas pipeline projects. The United States and a number of other oil-producing countries, including Saudi Arabia and Venezuela, quickly moved to make up for the embargoed Iraqi and Kuwaiti production.

Last September, DOE told Congress that a number of midterm steps were planned for implementation over the next 18 to 24 months to stimulate domestic oil production and energy efficiency. These include expedited processing of permits for additional oil production in Alaska's Beaufort Sea area, providing more natural gas for generating steam used in enhanced oil recovery in California, looking at ways to further reduce the 5–6% of electricity that is still generated with oil, promoting plants that convert municipal waste to energy, and accelerating plans to purchase alternative-fuel vehicles for the federal fleet.

DOE submitted a draft National Energy Strategy to the president last December. In a report earlier last year summarizing public comment, the department indicated that the report to the president would contain recommendations within an extensive set of policy options. News reports after that time were based on leaks about individual option papers submitted to the cabinet's Economic Policy Council for review.

Options reportedly considered ranged from taking measures that encourage accelerated domestic oil and gas production, to raising automobile fuel efficiency standards, to increasing taxes or adding new taxes on gasoline and other energy forms. Electricity-related options reportedly included new policy and regulatory support for various efficiency and demand-side management measures under the concept of integrated resource planning, plus steps to increase transmission access and competition in wholesale power markets and to reform nuclear plant licensing.

Some reports suggested that President Bush might incorporate some of the elements of the energy strategy in the fiscal year 1992 budget, to be proposed to Congress in January of this year. Complete details of the administration's energy strategy are expected to be presented in a report to Congress this April.

While the specifics of the National Energy Strategy were difficult to predict at the time of this writing, its likely themes, goals, and policy dilemmas were fairly clear, having been debated for some months by energy and economics experts in both government and business. For some perspective and background on the issues, the *EPRI Journal* turned to senior individuals among the Institute's management and advisers in a series of recent interviews.

Perspectives drawn from the ranks of EPRI's Advisory Council range from those of former federal energy and resource agency officials Robert Fri, Donald Hodel, John Sawhill, and Stewart Udall to those of John Gibbons, who directs Congress's Office of Technology Assessment, and Henry Linden, former head of the Gas Research Institute and now a senior energy academician.

From within EPRI, President and CEO Balzhiser, Presidents Emeriti Chauncey Starr and Floyd Culler, Senior Vice President Kurt Yeager, and EPRI Fellow Sy Alpert, along with consultant Sam Schurr, added their perspectives on the nearly two decades of the Institute's role in the matter of national energy policy and related science and technology. The insights and comments gleaned during the interviews are marked by a sense of déjà vu from individuals' past experiences in helping to develop national energy policies, together with strong, clear messages about what the United States should do to take control of its energy future.

Among the points on which substantial agreement was apparent is that it is exceedingly difficult to create a National Energy Strategy that will endure beyond current pressing concerns or political alignments, but that we should keep trying. Also, there was recognition that energy policy is now intimately interrelated with economic and environmental goals and cannot be considered in isolation. "Energy is not an end in itself," notes Richard Balzhiser. "The fundamental goals we should have in mind are a healthy economy and a healthy environment. We have to tailor our energy policy as a means to those ends, not just for this country, but in global terms as well."

There was also wide agreement that the American economy offers substantial opportunities to cut waste and wring more efficient and productive use out of all energy forms, serving the three social objectives of economic productivity, energy efficiency, and reduced environmental impact.

The largest and most challenging target of opportunity for change in energy use and technology is personal transportation. Without significant changes in this area, many of the fundamental problems of energy supply and demand in the United States will only grow, as the nation's fleet of over 170 million vehicles and the average number of miles they travel continue to grow. In transportation, as in the other sectors of the energy economy—industrial, commercial, and residential—efficient end use of electricity is a key technological ingredient that can improve any system's economic productivity and environmental performance.

Electricity's highly leveraging role in energy and technological transformation makes it a driver of expanding, but less energy-intensive, economic productivity. Adequate supplies and affordable costs of electricity, therefore, are essential to economic well-being. National energy policies should seek to maintain the availability of all resource options for the generation of electricity that can economically compete with other energy options, taking into account, to the extent possible, the costs of environmental controls.

As is reflected and amplified in the larger national debate about energy policy, however, there was less than unanimity among those interviewed about many specifics of how the country should pursue the laudable goals upon which most people will agree. The choice of policy instruments and inducements, the mix of government mandate and market freedom, the preferred technologies for accelerated R&D support, the relative importance of emerging global considerations for near-term domestic policy—these and many other particulars drew responses as varied as one might expect from a group of seasoned energy professionals.

Goals and challenge remain much the same

Most of those interviewed believe that trying to define or develop a National Energy Strategy—setting intermediate and long-range goals, together with policy measures and an R&D program designed to achieve them over time—is desirable but very difficult. "The history of U.S. energy policy is not very robust in terms of the country's sticking with it for very long. Policies are written but are later abrogated or forgotten, and events tend to overwhelm the assumptions used in setting policy. But we keep trying," says Sy Alpert, an EPRI Fellow. Alpert served on a National Research Council panel that recently assessed the technologies for producing alternative liquid transportation fuels from domestic resources.

Floyd Culler, former EPRI head and former deputy director at Oak Ridge National Laboratory, says, "A basic problem is that we do not have the political mechanisms that would allow an energy policy to be pursued for longer than two to three years at a time, or long enough to show results." He cites many of the promising projects for alternative fuels from coal and shale initiated under Project Independence and further supported under the synfuels program as victims of such lack of perseverance.

Culler and his predecessor at the helm of EPRI, Chauncey Starr, stressed—as did others—the long periods of time required for significant change in energy systems, whatever the policy direction, because of the inertia of the tremendous amount of capital invested in existing systems and infrastructure.

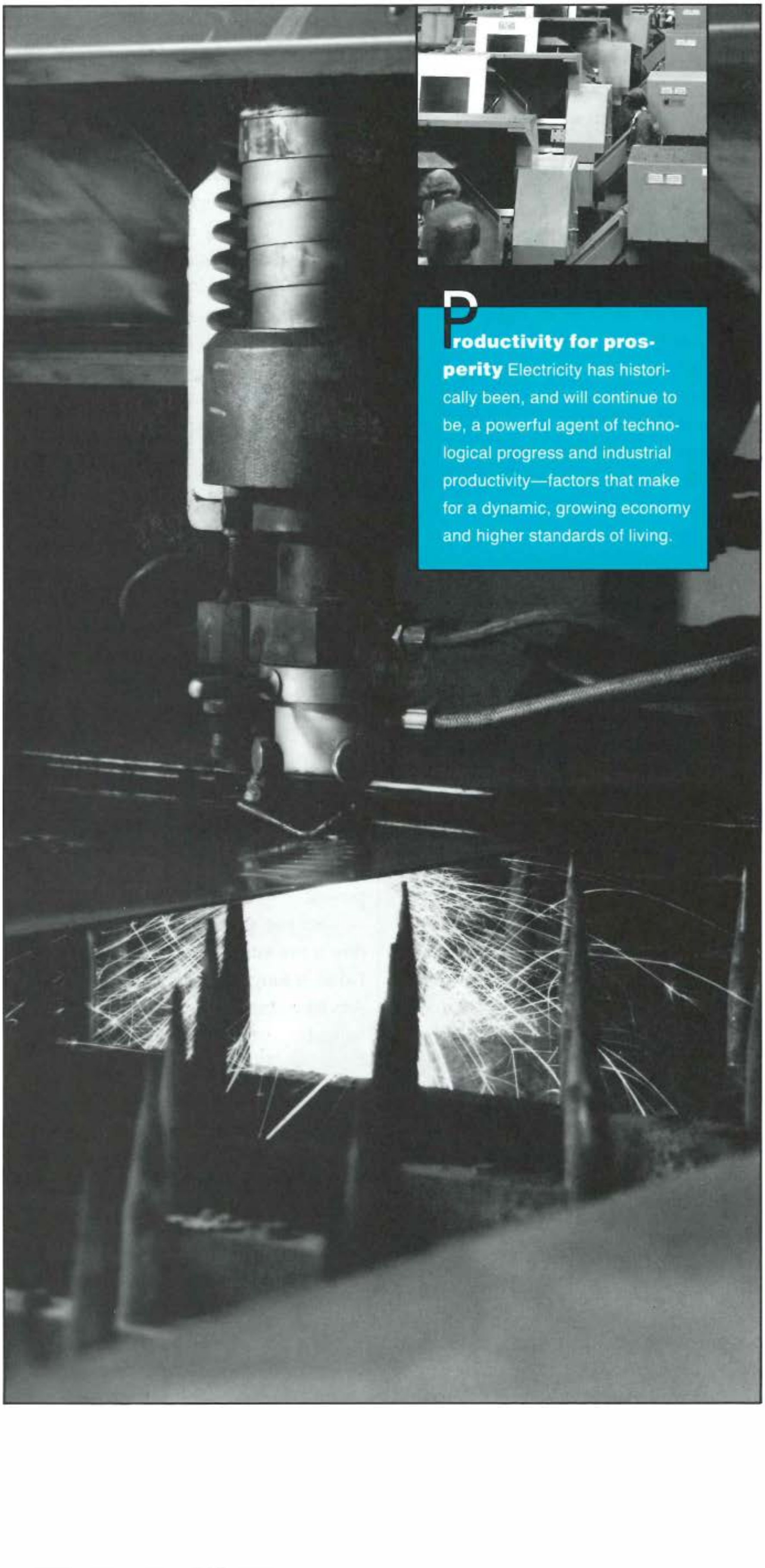
Starr says that over the short and intermediate term of up to 10 years, "market forces are what change things. If the price of oil goes up and stays up, people and the economy will go more for energy conservation and improved efficiency. Some people will even make modest life-style changes. But market forces and the private sector alone are insufficient to sustain a 50-year energy program, so there is indeed a major role for the government to play in energy policy if we are really going to make significant changes in energy supply and demand over the long term."

Many of those interviewed prefaced otherwise hopeful points of view with heavy doses of skepticism that this time around will be much different from previous efforts in terms of the ability of national leaders to rally and sustain public and political support for long-term energy policies. "Unless the administration can generate broad agreement on goals, direction, and specific policies, there will still be the same political problems that have plagued every past effort at national energy policy," says Donald Hodel, energy and interior secretary during much of Reagan's two terms.

Hodel says it was on his watch at DOE in 1983, in fact, that the first national energy plan was spelled out. "It was intended to be a comprehensive plan, and we had a goal that was thought about and fought over for a long time. We wound up with one that is the only correct and defensible goal of an energy policy: to ensure adequate supplies at reasonable costs. But the issue is, how do you get there? We had two principal strategies: first, to minimize federal intervention and control in the marketplace; second, to encourage a balanced and mixed energy supply, including alternatives, renewables, and conservation. It was clearly recognized that, as a nation, we need to reduce oil imports. How can the goal of energy policy be anything else? I would still debate anyone who thinks the policy should be anything but adequate supplies at reasonable cost."

Yet Hodel concedes that the lack of consensus across the many affected interests and constituencies was what ultimately crippled the ability of the government to do anything in energy policy during the Reagan years. "When you try to lay out a national energy strategy, every sector, group, and industry responds from its own vested interest to promote its particular path. Everyone moves in with his own special programs and wants the government to start picking winners and losers, which the government generally has done a poor job of."

And proposing an energy policy is far simpler than enacting one. Achieving an energy policy that really begins to reduce American dependence on imported oil "is like trying to reduce the budget deficit. Congress just has a very hard time with something this complex," says John Sawhill, who served several presidents in senior energy policy capacities and now heads the Nature Conservancy. "Every administration since Nixon's has tried to develop an energy policy in simi-



Productivity for prosperity Electricity has historically been, and will continue to be, a powerful agent of technological progress and industrial productivity—factors that make for a dynamic, growing economy and higher standards of living.

lar ways, holding hearings and synthesizing a lot of testimony from all the different constituencies, and frankly nobody has yet succeeded. In the end, the policy planners come up with something that's either so contentious they can't get Congress to pass it or so politicized that it doesn't do any good."

Sawhill directed government controls on oil and gas in the 1970s as the first federal energy administrator under Nixon and later was Carter's choice to head the new Synthetic Fuels Corporation. "Today," he says, "while there is a lot of talk about energy policy, I don't believe the political situation favors creating one. Because to have an energy policy, everybody's got to give up something —we've got to have higher gasoline prices, we've got to have some oil drilling in environmentally sensitive areas, and we've got to restart the nuclear option. Those kinds of things are pretty hard for people to accept."

One lesson from past experience that Sawhill and most others in energy policy circles today accept is that the government made a mistake when it tried to insulate the economy against market forces in response to the 1973 oil price shock. Many Americans remember waiting in long lines in their automobiles to buy gasoline, which was often gone by the time they reached the pump. Price controls "disrupted the flows of energy supplies and created shortages where they wouldn't have otherwise existed," says Sawhill.

Robert Fri, president of the Washington, D.C., think tank Resources for the Future and former deputy head of DOE's predecessor, the Energy Research and Development Administration, says the failure of government intervention in the oil market should be one of the major lessons of the 1970s. "I hope we learned that the price mechanism is the most efficient mechanism for allocating resources. We need to rely on the price mechanism to help solve our problems rather than trying to work against it," says Fri.

And that includes pricing energy to better reflect the true cost of producing and using it. Fri sees hopeful signs that public policy is beginning to internalize the cost of environmental externalities in energy prices. Among them are the tradeable emission allowances included in the Clean Air Act revision and continued calls for further increases in the gasoline tax beyond the small hike included in last year's budget compromise. Such moves should lead to more-effective market forces transmitting proper price signals to consumers and spurring greater energy efficiency.

"That's a lesson we've known for 40 years—that if the price of any resource goes up, you use less of it or you use technology to find more-productive ways of getting the same service. A technological response is induced by rising prices, and that is at the heart of the efficiency gains that have been made over the last decade," adds Fri.

Some observers point to more energy-efficient (but more heavily import-dependent) Japan or to European countries like France (which has substantially developed nuclear power for electricity generation) as models of more-effective government energy policy. And while most analysts of the U.S. energy scene say the complex domestic and international energy economy requires a blend of free-market forces with strong government policy and leadership, a decided contrarian is Henry Linden, now the Max McGraw professor of energy and power engineering and management at the Illinois Institute of Technology.

"The command and control approach to solving real or imaginary energy problems so popular during the seventies was, on the whole, a dismal failure," says Linden, who helped organize the Gas Research Institute and served as its president for many years. "I am totally opposed to the idea of creating another interventionist 'national energy plan,' which will be as doomed to fail as its predecessors.

"The United States—culturally, socially, and politically—simply is not Japan or France, where government-mandated solutions to interrelated energy, environmental, and economic problems seem feasible in spite of the disastrous record of central planning most everywhere else. If we allow market forces to play a major role, we can supply all of the energy services we need in the United States at both affordable cost and acceptable environmental impact."

But, Linden goes on, "we must also make the necessary market-responsive R&D investments on a timely basis. This is because energy supply, demand, and price and the environmental consequences of energy consumption are so exceptionally responsive to advances in technology. Although the large price elasticities of energy supply and demand are now reasonably well understood, they are small compared with the technology elasticities."

Zeroing in on efficiency

Another way of considering the significance of Fri's and Linden's technological response to higher energy prices is to see the now widely accepted potential for continued efficiency gains across all sectors of the economy as representing alternative, and some of the least expensive, forms of energy supply. Because efficiency can also mean increased productivity with lessened environmental impact, experts now widely agree that more-efficient use of energy should be a first-order priority in an energy strategy. It is also seen as a viable policy in the ongoing international discussions on strategies to address the potential for global climate change. U.S. officials at the World Climate Conference in Geneva last November maintained the Bush administration's resistance to immediate reductions of greenhouse gas emissions but suggested that the centerpiece of the administration's energy strategy would, indeed, be conservation and efficiency.

"Efficiency has got to be at the top of our agenda," says EPRI's Balzhiser. "It makes sense from an environmental standpoint, and it makes sense in terms of economic competitiveness. To make it happen, we need to price energy more strategically. Price is the key signal that will induce investment in new and more-efficient energy technologies, if stability is assured both by market forces and by sound public policies. In regulated energy markets, the latter play a particularly important role. With electricity rates established largely at the state level, we've seen a variety of approaches to encourage accelerated use of more-efficient technologies. We've had, in effect, many ratemaking experiments going on simultaneously in the real world, from which utilities and regulators will be able to identify optimal approaches for accommodating both the public and private interest."

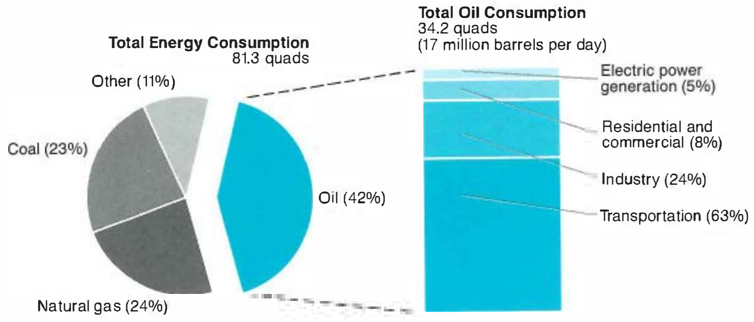
There seems to be wide consensus among analysts that substantial further gains in efficiency must include in a major way the transportation sector of the economy, which accounts for nearly two-thirds of the country's total use of oil from both domestic and foreign sources. Ultimately, that could mean reversing the dominance of the American consumer's demand for speed, size, and power.

"Our automobile culture as it exists today is not sustainable," says Stewart Udall, a longtime environmentalist who served as interior secretary in the Johnson administration and is now a private attorney. "With it, we have encouraged suburban sprawl, destroyed the railroads, and eliminated or diminished the importance of public transportation to the point that today we have an unbalanced transportation system. This imbalance is reflected in the demand for oil imports as the biggest and most unmanageable part of our trade deficit."

The ubiquity of personal vehicles as a symbol of American freedom and the depth of their role in the economy make them the heart of the discrete problem of

U.S. Energy Consumption in 1989

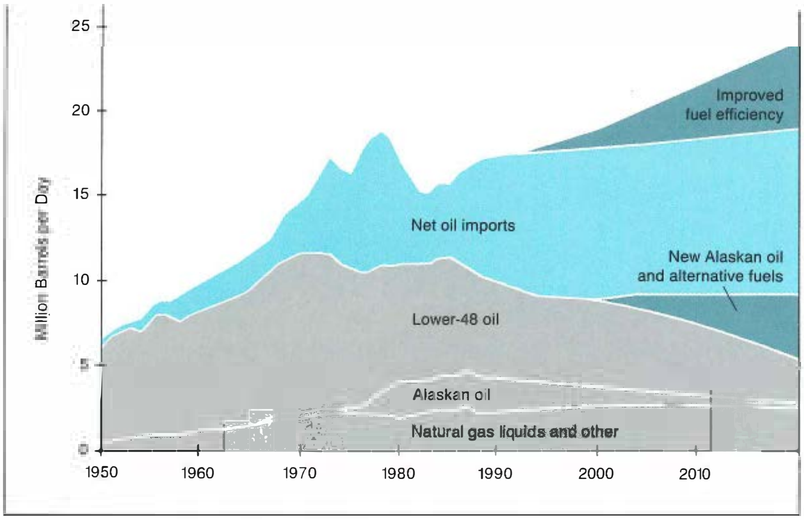
National security is closely linked with diversity and flexibility in energy supply. The dominance of oil in our energy mix—particularly as a transportation fuel—has not yielded to past energy policies, and our continuing dependence on this energy form is the principal threat to our energy security.



Source: U.S. Congress, Office of Technology Assessment.

Holding the Line on Imports

According to Congress's Office of Technology Assessment, dramatic efforts will be required over the next several decades simply to hold oil imports at the current 50% level. Projected increases in demand will have to be cut significantly by raising fuel efficiencies from the present average of 28 mpg to a mandatory 50 mpg for new cars and light trucks. At the same time, domestic fuel supply will have to be augmented by new resources from Alaska and by aggressive development of alternative fuels.



Source: U.S. Congress, Office of Technology Assessment.

liquid transportation fuel supply. Transportation represents the most difficult energy-consuming sector for national policy to do something about without significantly dampening the economy or curtailing consumer choice.

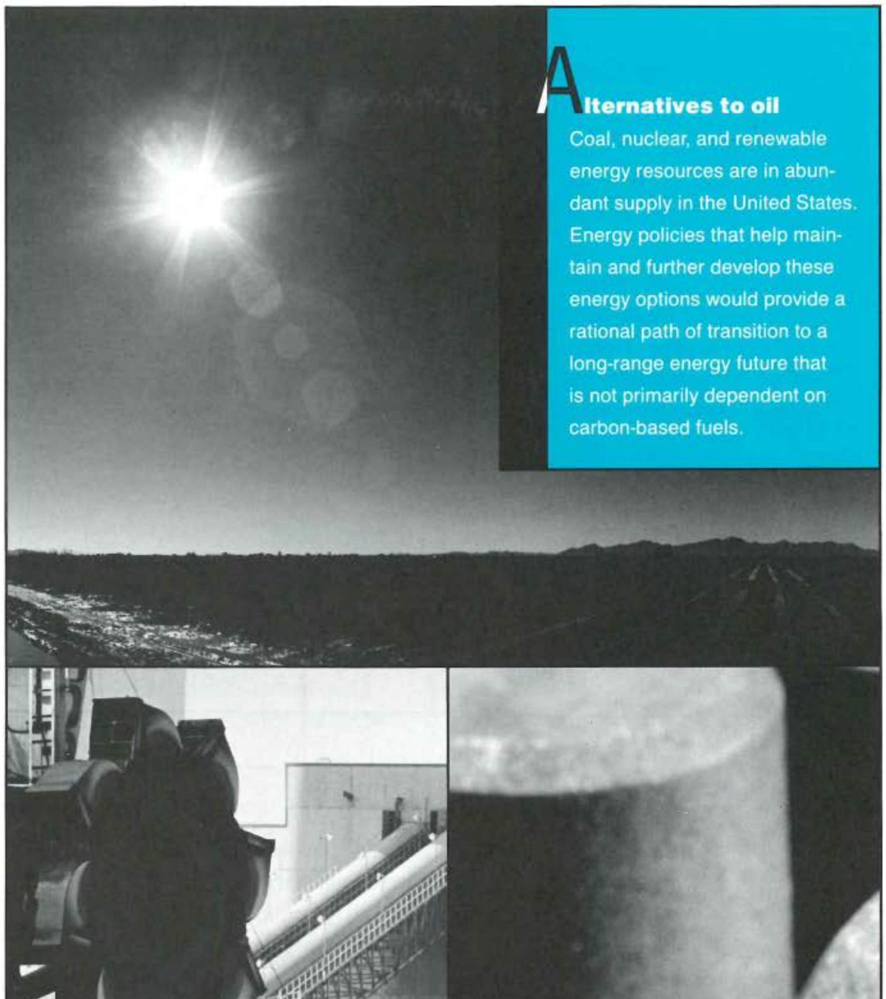
In wide-ranging energy testimony last fall before the House Budget Committee, John Gibbons, director of the congressional Office of Technology Assessment, said OTA believes there is substantial potential for further increases in fuel economy (beyond those largely achieved in the 1970s) through purely technological means that do not diminish consumer choice in the near term. Gibbons said OTA reckons that the average fuel economy of new cars could be pushed to 31 miles per gallon by 1995 from its present 28 mpg, and to at least 36 mpg by 2001. "Longer-term progress, beyond the year 2000, could be much larger if strong, continual incentives for fuel economy are brought to bear on the industry," said Gibbons. Larger gains, beyond those achievable through strictly technical fixes, would require Congress to mandate a basic shift in average vehicle size and performance either through regulatory or economic means, he added.

"It's likely that we'll see a real run on the auto in Congress in 1991," says Fri of Resources for the Future. "It's hard to imagine containing the growth of oil consumption without doing something to improve the efficiency of automobiles." But Fri, a current member of the secretary of energy's advisory board, says further tightening of the government's corporate average fuel economy standards could make it even more difficult for U.S. automakers to compete. An alternative would be to use the tax structure to favor gas sippers and penalize gas guzzlers.

In his congressional testimony, Gibbons said OTA believes that "alternative fuels present a key long-term opportunity to reduce U.S. oil dependence. Over the next few decades, alternative fuels derived from natural gas—both methanol and compressed natural gas—and from biomass [ethanol fuels] should be capable of substituting for a significant fraction of transportation petroleum use. Electric vehicles, perhaps employing not only batteries but fuel cells or other hybrid engines, could also be important possibilities in some regions of the U.S." In California, he noted, regulations have been adopted that could require the use of some ultralow-polluting vehicles by the end of the decade.

A more aggressive energy strategy to actually reduce oil use would depend on the availability both of substantial amounts of alternative fuels and of 50-mpg cars and trucks by 2020, along with the substitution of other energy forms for half of all nontransportation uses of oil, said Gibbons. But short of that, "dramatic and sustained efforts would be required to hold down oil import dependence over the next several decades—even to the present level of 50%."

While everyone seems to agree that improving energy efficiency offers the greatest opportunities in the short run to address all three Es in the energy-economy-environment triad, the potential actually represents a resumption of a long-term economic trend that has only recently come to be recognized and understood. "In the American economy during a period of rapid long-term growth, from 1920 to about the middle of this century, we used absolutely more energy, but the ratio of energy use to national output kept going down during that period," notes Sam Schurr, an EPRI consultant and former associate at Resources for the Future. "We were using more energy relative to the other production inputs, such as labor and capital. But in using more energy we improved overall economic efficiency and therefore saved in combined total inputs per unit of output, and that included savings in energy use per unit of output. That is the essence of productivity growth." This conclusion is elaborated in a book by Schurr and others published last year by Greenwood



Alternatives to oil

Coal, nuclear, and renewable energy resources are in abundant supply in the United States. Energy policies that help maintain and further develop these energy options would provide a rational path of transition to a long-range energy future that is not primarily dependent on carbon-based fuels.

Press—*Electricity in the American Economy: Agent of Technological Progress.*

Schurr says a competitive market economy will naturally seek the most efficient equilibrium among the factors of production. "If you can find ways of using energy more efficiently without making energy saving the paramount objective, so much the better. To achieve such results, as actually happened during much of the twentieth century, it seems to me that electricity has all the virtues we should want.

"Throughout the twentieth century, electricity has been an agent of technological progress, and it will continue to be so—more than any other energy form. And technological progress is what makes for a dynamic and growing economy and is what accounts for rising standards of living. For most of the century, because of the proliferation of electrified production technologies, electricity use grew faster than the economy, and it is now growing at about the same rate. And its use has grown at a far more rapid rate than the combined use of all other forms of energy." Schurr concludes, "I would make electricity a major ingredient in an energy strategy, because it serves technological progress, it enables you to use a variety of domestic resources in its own production, and it solves or at least makes more manageable a number of environmental problems."

Taking the long view

Substituting electricity into more end-use applications of energy could represent more than Schurr's agent of technological progress. It could also represent a rational path of transition to the longer-term future. If science confirms what is suspected about the nature and magnitude of potential climate change induced by greenhouse gases, including carbon dioxide, highly electrified societies will be best positioned to begin to move away from fossil fuels, both for transportation and in all other uses, including electricity generation.

"Over the near term, electricity must be seen as the vehicle that permits the processing of domestic resources that we have in abundance—coal, nuclear, and renewable resources—with the least degree of waste, and that also enables the use of new technologies on the demand side to improve efficiency," says EPRI's Kurt Yeager, senior vice president, technical operations. That processing depends on advanced technologies—such as gasification–combined cycles and fuel cells—that will permit more-efficient use of coal, as well as of urban refuse and biomass, with dramatically reduced environmental impact.

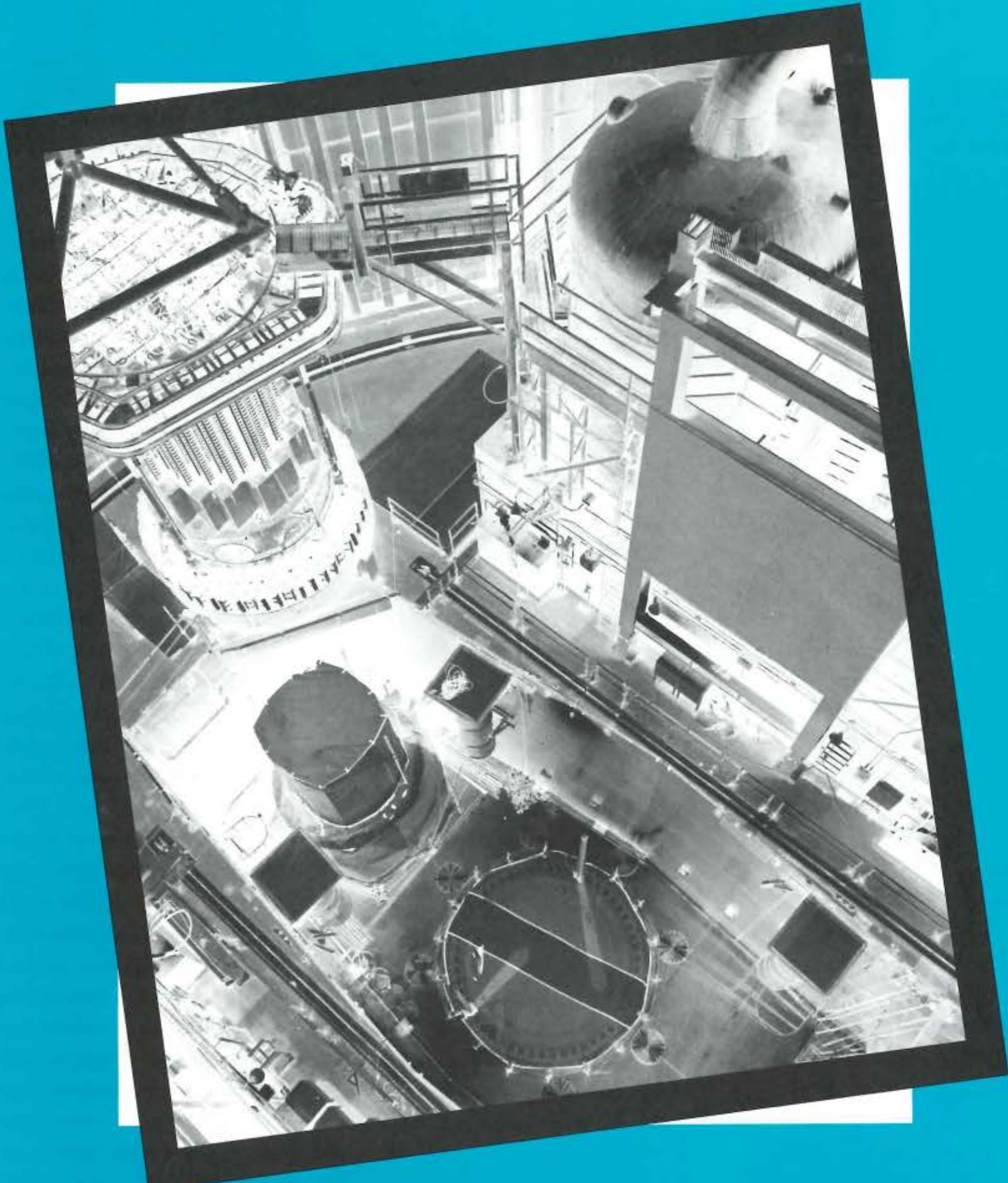
"But an energy policy should also be built around a long-term R&D program with the ultimate aim of making the transition to a managed energy supply without limits, relieving us of primary dependence on hydrocarbon fossil fuels," adds Yeager. He says that, in addition to setting domestic policy goals consistent with that vision, "the United States and other countries of the world should set a goal of increasing global energy efficiency by at least one-third over the next 50 years and another goal of establishing the technical and commercial base to reduce primary dependence on carbon-based fuels over the same period.

"The policy challenge is not to demonstrate the value of such measures in 50 years but, rather, to begin the investment process now that assures that end." Yeager continues: "Whether the developed countries, particularly the United States, can focus the necessary resources on such a long-term strategic issue when the incentives in our society preferentially reward short-term gain is an open question. Resolving it requires the same national commitment to our resource and technology strengths that has marked the American consensus on military defense over the past 50 years. Regrettably, it seems that it requires escalating but avoidable crises—such as war in the Middle East—before our society can forge and maintain a consensus on energy policy as an essential element of global prosperity and security."

OTA's Gibbons believes that a candidate goal for U.S. energy policy should be to begin now to reduce the overall fossil fuel intensity of the national energy economy by an average of 1% a year and to maintain that transition rate for at least the next two decades. He says that because of the specter of air pollution and climate change, the fossil fuel era "may need to end, not in centuries, but in a century or less. This means that solar and nuclear power (fission and fusion) must be considered as the energy sources for mankind that may soon have to become globally dominant, perhaps within 50 years." In political and quarterly-earnings-oriented business terms, 50 years seems like a long time, yet it is about the minimum period that analysts such as Schurr, Starr, and Culler say it takes to really change the energy systems of nations.

As Gibbons puts it, "It is important to recognize that there are no energy 'fixes' that are easy or quick. We will succeed in easing U.S. oil dependence only if we set long-term efficiency and supply goals, set up long-term import management goals, and stick to the plan to achieve those goals through periods of both crisis and calm and through periods of high and low oil prices. Major changes in energy systems—and major changes are what must occur—require decades and unwavering commitment from citizens, political leaders, and industry. A sensible, comprehensive energy strategy must be responsive to sudden changes of events, but it must be fundamentally grounded in long-term strategies." ■

This article was written by Taylor Moore.



PROBABILISTIC RISK ASSESSMENT

Prescription for Severe-Accident Prevention

After more than a decade of intense effort, the electric utility industry and the Nuclear Regulatory Commission (NRC) appear close to resolving some of the most critical safety issues raised by the accident at Three Mile Island. These issues focus on reactor behavior that could lead to severe accidents and on what can be done to further prevent, and mitigate the effects of, such accidents. Achieving regulatory closure on severe-accident issues has required the development of a fundamentally different approach to safety analysis than that used before Three Mile Island, and EPRI is playing a key role in developing the data and tools utilities will need to perform such analysis individually on every nuclear power plant in the country.

Since the early days of nuclear power, safety efforts have focused on demonstrating that nuclear plants could handle certain "design-basis events" without damage to the plant or fission-product releases to the environment. The regulations that evolved during the late 1960s and early 1970s limited consideration of design-basis events to those judged to have the potential of occurring during the lifetime of the first-generation plants. The most severe of these events was postulated to be a loss-of-coolant accident, or LOCA, such as a break in a large pipe that would release coolant from the reactor. Postulated LOCAs were used as the basis for designing both emergency cooling systems that could keep a reactor core covered with water and containment buildings that could prevent the release of radioactivity to the environment. Over the years, additional design-basis events have been added in response to operating experience. A defense-in-depth philosophy was also adopted, providing backup safety systems that would offer protection even if an accident progressed beyond the design-basis assumptions.

What the accident at Three Mile Island showed was that a series of small malfunctions and operator errors could esca-

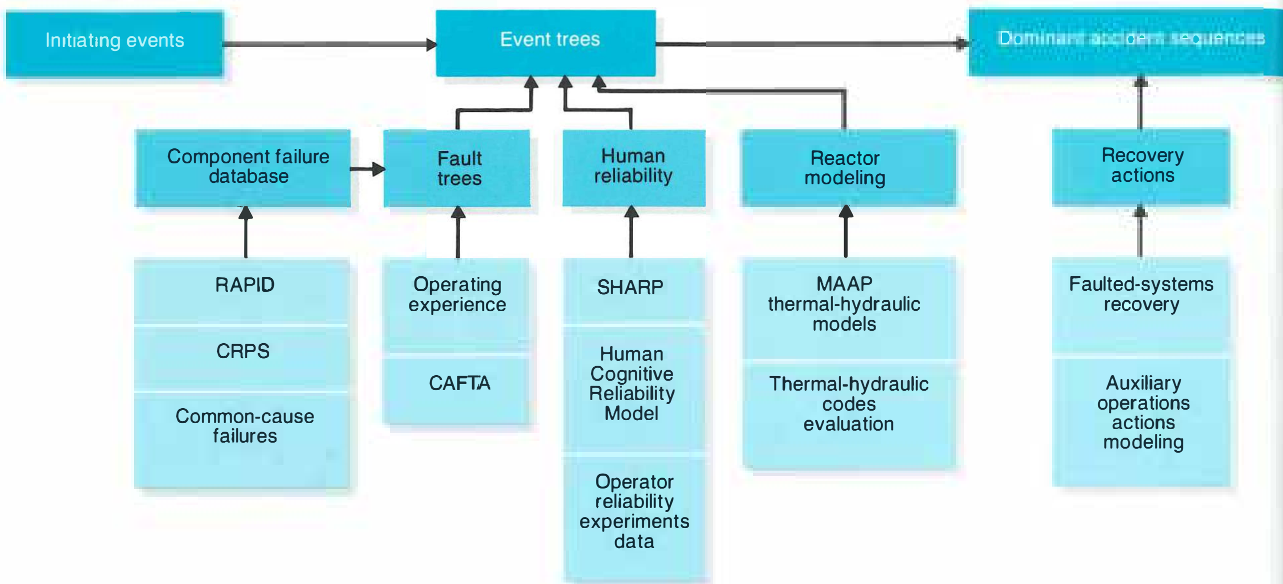
THE STORY IN BRIEF

One of the clearest lessons learned from the Three Mile Island nuclear accident was that an unfortunate sequence of seemingly small misjudgments and malfunctions could lead to an accident more severe than that from a large-break LOCA. In response, the electric power industry and the Nuclear Regulatory Commission have adopted a fundamentally different approach to safety analysis—one based on probabilistic risk assessment, a mathematical technique for identifying and ranking the importance of event sequences that could lead to a severe nuclear accident. The effort involves conducting an individual plant examination for each nuclear power plant in the United States in light of knowledge gained since TMI. On the basis of information about the most likely accident sequences for their individual plants, utilities can make equipment and procedural changes, if necessary, to counteract vulnerabilities and can make more effective plans for managing an accident, should the need arise.

Road Map for Individual Plant Examination

The individual plant examinations (IPEs) that are now being conducted nationwide apply the mathematical tools of probabilistic risk assessment to investigate the likelihood of severe nuclear accidents. The so-called front-end IPE analysis starts with considering how certain initiating events (such as a pipe rupture) could trigger various accident sequences and ends by calculating the frequency of core damage for each sequence. Back-end IPE analysis begins with the assumption of core damage and determines the frequency and

Front-end analysis

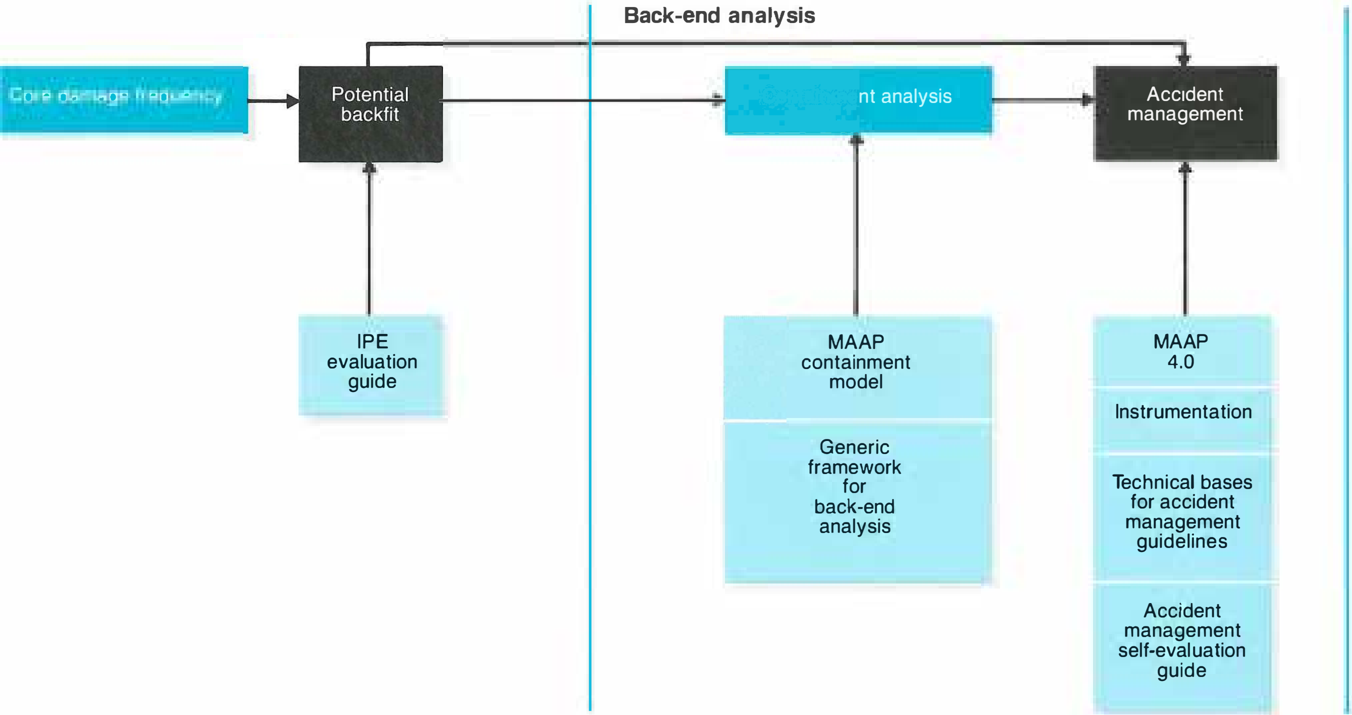


late into an accident more serious than a large-break LOCA. As a result, safety analysis began to focus more on identifying a variety of event sequences that could potentially lead to a severe accident. This kind of sequence might begin, for example, with a steam generator tube rupture or a station blackout. The analysis then focuses on finding ways to reduce the likelihood of these sequences and to terminate them at different stages. A utility might, for example, consider increasing the size of the batteries that are required for operating certain valves and instruments in the event of station blackout.

The mathematical approach taken in this type of analysis is called probabilistic risk assessment (PRA). Typically, it entails the use of a structured examination process and computer codes to determine what accident sequences can occur, calculate the likelihood of each, and predict their consequences. In order to provide closure on severe-accident issues, the utility industry and the NRC have agreed to use the PRA approach to assess risk and enhance the safety of each U.S. nuclear power plant.

"This effort is an excellent example of how the industry and the NRC can work together in the absence of mandated rules and under nonadversarial conditions to ensure nuclear safety," says EPRI's Karl Stahlkopf, director of safety technology in the Nuclear Power Division. "EPRI work represents the core of the industry's technical response: it is providing a large number of products utilities can use in making probabilistic risk assessments and implementing severe-accident management guidelines based on these assessments."

Albert Machiels, a program manager in the Nuclear Power Division and the matrix manager of its work on severe accidents, agrees: "This is the first time that a regulatory agency and an industry have agreed to apply probabilistic risk assessment across an entire class of facilities. Such an agreement indicates, first of all, potential severity of releases of radioactive products outside the plant's containment structure. The analysis results can lead to safety enhancements through equipment backfits and/or revisions to operational procedures and accident management guidelines. A number of EPRI-developed models, guides, and data sets are available to help carry out the analysis.



the maturity of the PRA approach, and EPRI has developed more than a dozen products to help utilities conduct PRAs at their nuclear plants. In addition, EPRI has assembled an international research consortium that is conducting experiments to fill in gaps in the knowledge needed for these safety analyses."

How safe is safe enough?

In order to achieve closure on safety issues by using probabilistic risk assessment, there must be a standard of what risk is acceptable, since virtually no human activity can be made perfectly safe. Before Three Mile Island, the NRC took what is usually called a deterministic approach to safety—that is, it accepted a nuclear plant as safe enough if the plant was built to withstand a set of design-basis accidents. In a probabilistic approach, on the other hand, quantitative objectives must be set to assess the achievement of safety goals.

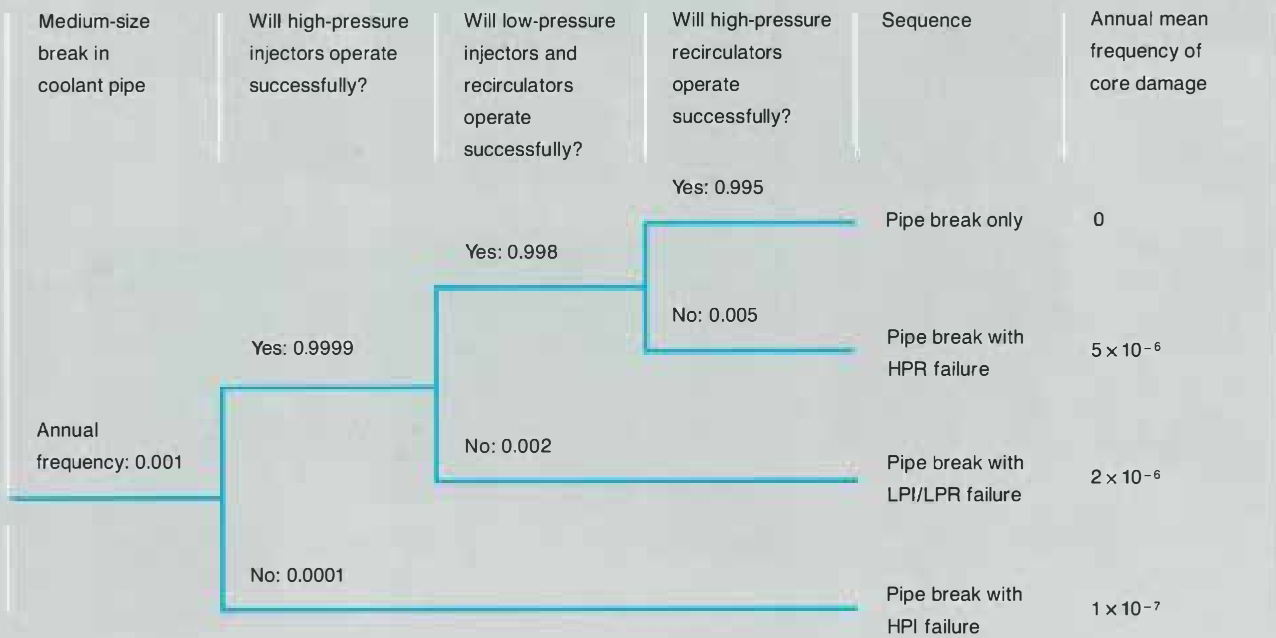
In addition to other regulatory actions related to PRAs and severe accidents (see box, page 22), the NRC issued a policy statement in 1986 quantifying a key safety goal: that the risk of dying from a reactor accident for a person near a nuclear power plant be less than one-thousandth of the risk of dying from other accidents to which people are ordinarily exposed. Such a risk works out to about one chance in a million that anyone near a particular reactor would be killed in a particular year.

This figure has also been translated into performance objectives for accident prevention at existing nuclear power plants. Specifically, to meet the risk-of-fatality goal, the frequency of accidents resulting in severe core damage should be kept below one in 10,000 reactor-years of operation. For future nuclear plants, the comparable objective—specified by the *Advanced Light Water Reactor Utility Requirements Document*—will be one severe accident in 100,000 reactor-years.

Because each nuclear power plant is unique, determining whether the stated

Probabilities for Accident Sequences

The central IPE task is to develop event trees, which investigate the sequences of events that may follow accident initiation and which calculate the frequency of outcomes on the basis of actual industry experience with component failure and operator reliability. By considering entire sequences of occurrences, event trees can quantitatively identify weak spots in a plant's safety defenses. The highly simplified sequence shown here lays out the potential likelihood of sustaining reactor core damage from a medium-break loss-of-coolant accident.



safety objectives are being met will require plant-by-plant examinations using probabilistic risk assessment. Called individual plant examinations (IPEs), these are already under way as part of the industry-NRC severe-accident-issue closure plan. The IPEs will provide utilities with valuable insights about specific problems that may be present at particular plants. In addition, the NRC intends to compile an industrywide profile of reactor performance based on the examinations to determine the adequacy of existing regulations.

An IPE consists of a probabilistic risk assessment and an evaluation of the results. The primary tasks are to look for vulnerabilities to severe accidents and to identify cost-effective safety improvements that would reduce or eliminate the most important ones. One example of such a vulnerability came from study of the accident at Three Mile Island, where the control room configuration made the job of controlling the accident more difficult. New configurations have been developed to reduce this vulnerability.

Conventionally, each IPE is divided into a front-end analysis, which is concerned with events leading up to core damage, and a back-end analysis, which deals with events from the onset of core degradation to the release of radioactive material from the containment building.

A front-end analysis begins with data on the frequency of initiating events—events, such as a pipe rupture, that could potentially lead to a severe accident—and ends with a quantitative estimate of core damage frequency. The various sequences of events that could take place between initiation and damage make up the "event tree" of a particular accident. Such event trees are constructed by using four basic kinds of inputs: a thermal-hydraulic model of the reactor as a whole, a model of how various components are likely to fail (called a fault tree analysis), a database of actual component failures, and a model of operator reliability.

EPRI has produced computer codes or

databases in each category, some of which are well on their way to becoming industry standards. Of particular importance are MAAP (Modular Accident Analysis Program), which incorporates a thermal-hydraulic model for use in analyzing accident sequences, and CAFTA, which performs fault tree analysis.

"EPRI's MAAP and CAFTA codes are the workhorses of our utility's PRA effort," says Duncan Brewer, a design engineer at Duke Power. "We use them daily. Previous codes were much more difficult to apply."

David Dion, a nuclear engineer at Pacific Gas and Electric, describes another application: "We used MAAP to support a PRA conducted as a condition to operate Unit 1 of the Diablo Canyon plant. We had to do 30 or so scenarios related to the loss of ac power for periods extending from 4 to 80 hours. It was the only feasible tool; I don't think any other code could have done the job in a reasonable time." PG&E has also used EPRI software to assess the reliability of its control room crews—an application carried out in conjunction with simulator drills involving event sequences that could lead to severe accidents.

From the various accident sequences identified by the event tree analysis, engineers can select certain dominant sequences for further study. In particular, they try to see how these accidents-in-the-making can be halted. After such recovery actions are taken into account, core damage frequency is computed and recommendations are made about possible backfits of equipment and procedures to enhance safety.

Accident management

Once a hypothetical accident has progressed to the point of core damage, attention turns to preventing radioactivity release outside the containment building and to bringing things under control. The IPE back-end analysis attempts to quantify the likelihood of radioactivity release from the containment and attached buildings. Accident management is not concerned with quantification; rather it starts with the assumption that events have already progressed beyond the design basis of the plant and focuses on finding ways of successfully solving the problem.

Accident management strategy is described by EPRI project manager Richard Oehlberg: "Ultimately it has to be operational—what would actually be done by people at a plant, under pressure. Accident management involves dealing with the unlikely rather than just determining risk, as in IPEs. It means considering all your options and thinking ahead about how to apply them in emergency situations."

Recognizing the importance of such questions, EPRI is supporting an industry initiative in accident management by preparing the *Accident Management Guidance Technical Basis Report*, which describes the recommendations of top industry experts for coping with accidents. This document is intended to provide the basis for plant-specific guidelines, which will be produced by reactor owners groups and individual utilities. EPRI is also leading a design review team to ensure the practical operational character of the document.

Filling knowledge gaps

In order for PRAs to be performed, computer codes like MAAP must be able to make complex calculations regarding reactor behavior during accidents. Such modeling requires detailed information about the uncommon physical and chemical reactions that may occur under these extreme conditions. The formation and release of radioactive compounds, for example, have been of particular concern.

Some of the experiments that must be performed to provide the needed data in this area require relatively large, highly specialized facilities. Because the results will be so widely applicable, EPRI has been able to assemble a consortium of nuclear organizations from some 20 countries to help sponsor these costly experiments. Begun in 1985, this experimental program has already produced valuable insights that have led directly to closure

State-of-the-Art Control Room

Analyses of the Three Mile Island accident identified control room reconfiguration as one key to enhancing plant safety. As a result, control rooms now feature improved instrument grouping and real-time video displays to help operators quickly obtain an accurate picture of what's going on inside a reactor. Similarly, probabilistic risk assessment takes a close look at other safety-related systems of individual power plants to identify retrofits and procedures that can help prevent or mitigate severe accidents.

of some severe-accident-related issues. Other experiments are still going on; final results from the current phase of the program are expected in 1992.

One of the first concerns was to find out how radioactive materials might be released and transported as aerosols. A series of experiments known as LACE (LWR Aerosol Containment Experiments) simulated aerosol production in a variety of accident situations and found that, because these tiny droplets tend to grow and settle rapidly, their ability to transport radioactivity outside the containment structure is limited. The LACE program, which was completed in 1987, produced 78 reports and a body of data that has become the world standard on aerosol behavior.

ACE and MACE

With the successful completion of that first set of experiments, the consortium launched an even more ambitious program called ACE (Advanced Containment Experiments). These experiments address three specific severe-accident issues: the behavior of radioactive iodine, the effectiveness of filtration devices, and the interactions of molten core material (called corium) with concrete.

Radioactive iodine has been a subject of much discussion since the early days of nuclear power because it is a common fission product, is chemically active, and can become concentrated in animal tissues. Initial estimates of the amount of iodine that might be released in a volatile form during a reactor accident were relatively high; measurements made at Three Mile Island, however, indicated an actual release that was only a small fraction of what had been predicted.

The ACE program has helped explain this discrepancy and has provided reliable data for modeling iodine behavior. Briefly, the experiments showed that most of the volatile iodine released promptly during an accident either gets caught in an aerosol and settles out of the air inside the containment structure or reacts chem-

Evolution of Reactor Safety Policy

The use of probabilistic risk assessment (PRA) to help evaluate reactor safety and provide input for nuclear policy is not new. The pioneering *Reactor Safety Study*, published by the Nuclear Regulatory Commission in 1975 as report WASH-1400, took a PRA approach in examining two typical nuclear power plants—one boiling water reactor and one pressurized water reactor. This study established risk profiles for the two basic reactor designs and is widely used as a reference throughout the world.

On the basis of data from WASH-1400 and from several subsequent PRAs, in 1985 the NRC issued the Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants (50 FR 32138). This policy statement declared: "On the basis of currently available information, the Commission concludes that existing plants pose no undue risk to public health and safety and sees no present basis for immediate action on generic rulemaking or other regulatory changes for these plants because of severe accident risk."

The NRC did, however, recognize that systematic plant examinations employing probabilistic risk assessment would be beneficial in identifying plant-specific vulnerabilities to severe accidents. To provide quantitative objectives for these examinations, in 1986 the commission issued the Policy Statement on Safety Goals for the Operation of Nuclear Power Plants (51 FR 28044). The controlling objective stated: "The risk to an average individual in the vicinity of a nuclear power plant of prompt fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1 percent) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed."

The NRC has recently updated WASH-1400. The new report, designated NUREG-1150, is based on probabilistic risk assessments at the two plants originally examined, plus three other plants. It will be published in 1991, but a draft version has already been widely circulated.

The updated analysis shows significant improvements in reactor safety, compared with WASH-1400, for two reasons. First, the physical safety of reactors has been increased as a result of modifications made by the industry. Second, the phenomena involved in severe accidents are now more fully understood and engineers are better able to quantify the risks involved. In particular, NUREG-1150 shows that the release of radioactive products from a nuclear plant containment structure would be significantly lower than previously predicted. □

ically with surface materials, such as metal and paint. The experiments also revealed that the best way to prevent long-term release of volatile iodine after an accident is to maintain alkaline conditions in the sump water that has been used to bring the nuclear reaction under control. According to EPRI project manager Robert Ritzman, the final stage in this part of the ACE program will address ways to optimize control of volatile iodine by applying the knowledge gained thus far.

Filters designed to remove radioactive aerosols from air being vented from a containment structure after a severe accident are popular in Europe, but the United States and countries in Asia have not chosen to allow containment venting in this way. The ACE program has included tests of eight European filtration systems, including one from the Soviet Union. All the filtration systems performed satisfactorily in the tests. Says EPRI project manager Mati Merilo: "This part of the ACE program has enabled our European partners to take advantage of U.S. facilities to test their filtration systems, while giving us an opportunity to evaluate the pros and cons of such systems."

The third component of the ACE program involves experiments on molten core–concrete interactions (MCCI), informally known as the "core-on-the-floor" problem. The main reason for undertaking these experiments is that large uncertainties remain about how much fission-product release would result from MCCI if a reactor vessel were breached and molten corium fell on the concrete basemat of the containment structure. The experiments are very expensive, since they require the use of several hundred kilograms of representative core material, which must be maintained at high temperature for hours by electrical heating. Most of the MCCI experiments have now been completed, and EPRI senior scientific adviser Raj Sehgal says that "they have provided the definitive data needed to close the issue of fission-product release once an accident has progressed to the point of core-on-the-floor."

Still unresolved, however, is the question of how plant engineers would cool the molten corium once it began to attack the floormat concrete. Sehgal says, "You don't need to worry about the 'China syndrome'—the core won't eat through the 12 to 14 feet of basemat concrete—but we do want to know how to quench the corium and terminate the accident." This question is the subject of the final set of experiments currently being undertaken by the international consortium. Called MACE (Ex-vessel Melt/Debris Attack and Coolability Experiments), this research has progressed to the scoping-test stage.

One problem encountered in the scoping test was the formation of a stable crust over the molten corium, which made quenching with water from above difficult. Most researchers believe that when the test is repeated at larger scale, the crust will prove unstable enough to facilitate quenching. The floor of a containment building that would be covered by corium is typically more than 20 feet in diameter. If a crust of that diameter formed, it would not be structurally stable. It would develop cracks and allow water to enter and quench the corium.

Looking ahead

In addition to conducting individual plant examinations and developing accident management guidelines, the utility industry is continuing to work with the NRC in other areas related to severe accidents.

Generally speaking, IPEs deal only with initiating events that occur inside the reactor system itself. In the future, the NRC is expected to request some sort of plant-by-plant examination of safety risks from external initiators, such as earthquakes and fires. Final NRC guidelines for conducting such evaluations, however, have not yet been issued.

Two related programs are expected to continue even after closure of the severe-accident issues as they are now understood. The NRC's Improved Plant Operations (IPO) Program is an ongoing effort to enhance operator licensing and training, performance evaluation, quality assurance, plant maintenance, and inspections. The NRC's Severe Accident Research Program (SARP) has long-term goals related to further understanding the full range of severe-accident phenomena and developing methods to assess and control fission-product release.

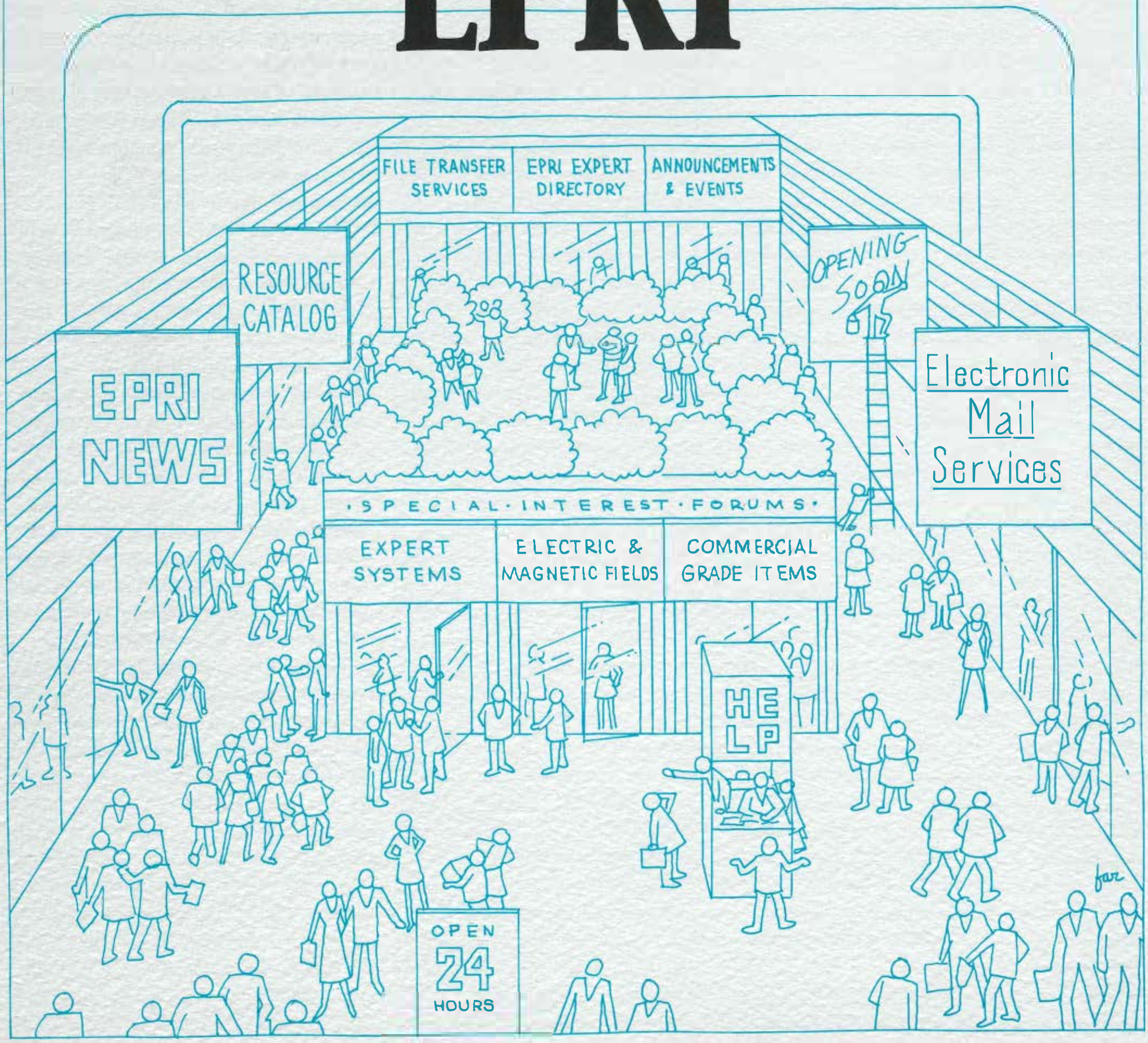
"We are very pleased with the NRC's past commitment in support of research programs related to severe-accident issues," says EPRI's John Taylor, vice president for nuclear power. "The results of the SARP effort, along with EPRI efforts and those of the European Community, have provided a strong scientific basis for resolution of these issues."

Ultimately, the responsibility for seeking closure with the NRC on severe-accident issues lies with the Nuclear Management and Resources Council (NUMARC), composed of representatives from all U.S. nuclear utilities. In particular, NUMARC's Severe Accident Working Group (SAWG) is working on industrywide guidelines related to IPE findings and accident management needs.

Cordell Reed, senior vice president for nuclear power operations at Commonwealth Edison, is the chairman of SAWG: "I think the biggest challenge facing nuclear utilities today is closure of the severe-accident issues. It's taken a long time to get agreement with the NRC on how to evaluate severe accidents and what constitutes closure, and now it's very important that we move ahead with the required work. Also, for the next generation of nuclear plants, safety expectations will be even higher, and we need to be fully confident that we know how to deal with severe accidents." ■

This article was written by John Douglas, science writer. Technical background information was provided by Karl Stahlkopf and Albert Machiels, Nuclear Power Division.

Computer Gateway to EPRI



When Ed Gastineau begins his day as director of research for Central and South West Services, he switches on his personal computer and taps in commands that connect the machine on his desk to a mainframe computer 1500 miles away—at EPRI headquarters in Palo Alto. After typing in his password, Gastineau can select from a menu of services that will lead him directly to the type of information he needs that morning. He can read about developments in a variety of EPRI R&D programs or the latest news on fast-breaking issues, find reports and articles on specific subjects by typing in plain English phrases, or identify an EPRI staff member with expertise in a particular area. He can also use an electronic mail service to send messages to the EPRI staff, to people in his own company, or to his colleagues at other utilities.

Ed Gastineau is one of hundreds of utility employees around the country using a new electronic information network, EPRINET™, to gain fast and efficient access to the Institute's store of knowledge, products, publications, and people. EPRINET links member utility staff with each other, with EPRI experts, and with contractors working on EPRI projects—cutting across geographic distances and time zones to provide easy and convenient access to EPRI and industry news, EPRI publications and software products, updates on research projects, electronic mail, and other features. In essence, EPRINET provides a gateway to the Institute, and the electric power industry, right on the user's desk top.

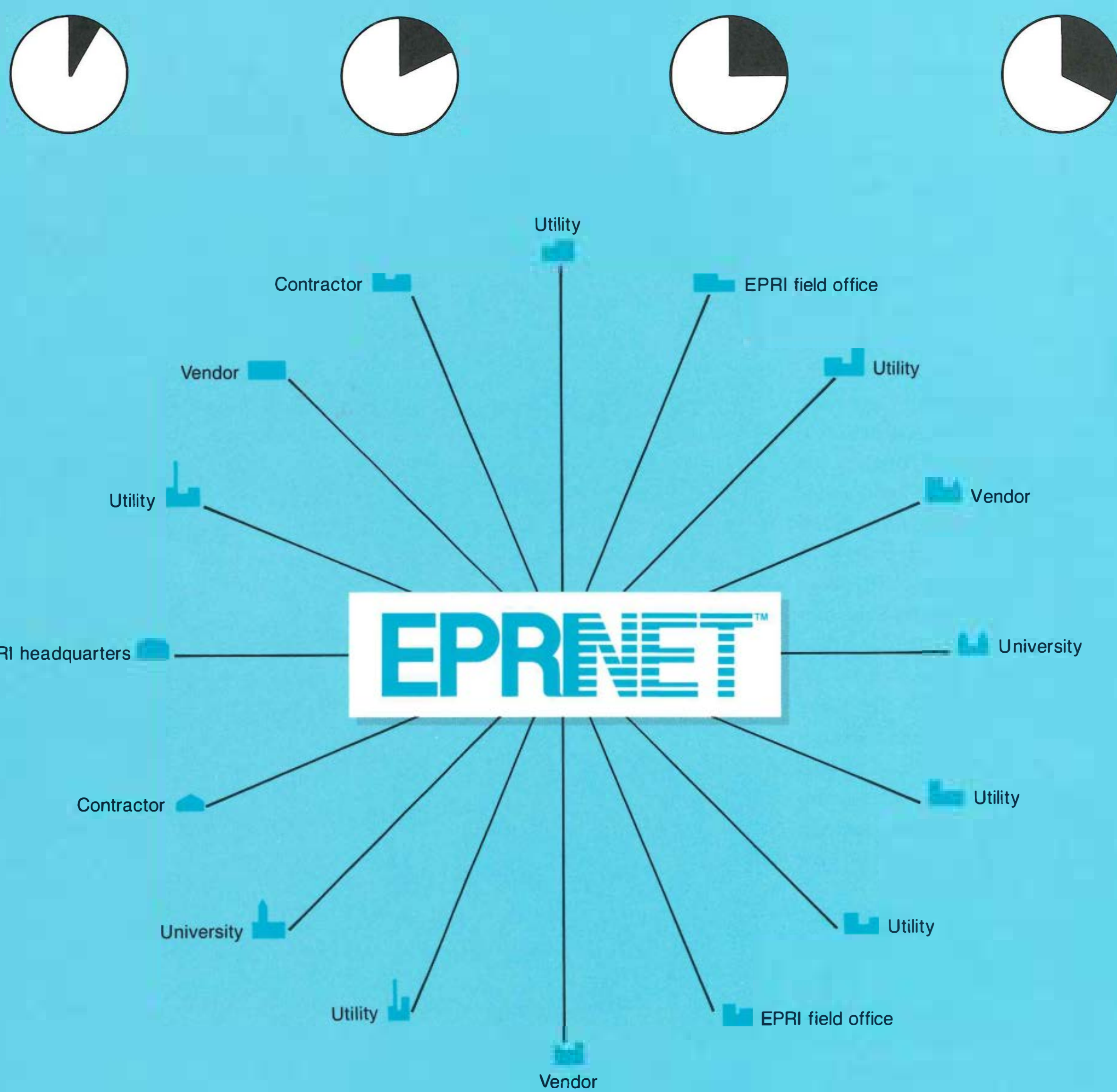
"I find the news services very helpful," says Gastineau. "Very often I'll be writing a report on some topic and I'll tap into EPRINET and find something very germane to the subject. Last week, for example, I was writing about electric vehicles and found an EPRINET news item about the market potential for electric vehicles that directly applied to my work." Many other utility employees are finding that

THE STORY IN BRIEF

EPRI is reaching out to utilities with a new product intended to provide easy, direct access to the Institute's store of information and knowledge. As an electronic information and communication network, EPRINET links a community of diverse users—member utilities, EPRI research managers, contractors, and R&D organizations around the country—transforming a user's desktop computer into a gateway to the Institute and the electric power industry as a whole. Forums on specialized topics promote real-time information exchange on such critical and fast-moving utility issues as EMF. EPRINET also provides a unique full-service interface to EPRI's work: participants can receive news and information about developments in ongoing R&D programs, search for and retrieve articles and reports on specific topics, identify key EPRI staff members with expertise in a particular area, and order publications, software, and other Institute products on-line.

Making the Right Connections

Cutting across geographic distances and time zones, EPRINET links member utilities with EPRI headquarters and field offices and with contractors, university research organizations, and vendors. In addition to gaining direct access to EPRI's store of knowledge and expertise, a network participant can communicate with any other member of the network.



EPRINET's direct access to the Institute and timely delivery of specific information are helping them realize more value from their EPRI membership.

Delivering the product

"EPRI's product is knowledge," says Marina Mann, director of EPRI's Information Technology Division. "Vast amounts of complex technical information are brought into the Institute, where our experts apply intelligence to that information to create knowledge. The challenge for EPRI is to effectively disseminate that knowledge to the staffs at almost 700 member utilities in a form that they can use to solve their problems." That's no small task. Consider 350 EPRI technical staff and a half-million or so member utility employees, and the problem is clear: opportunities for person-to-person connections are limited, and they are further restricted by a two- or three-hour time difference between EPRI's headquarters and many of its members. Yet in an increasingly competitive industry, utility problems often require quick answers and individual attention.

Since EPRI's founding in 1972, its history has paralleled that of the information age—a period in which personal computers have taken root on most desk tops, and fax machines and electronic mail have begun performing much of the work that used to be done via business letters and other printed material. While the explosive growth of computer and telecommunications technology has improved efficiency and productivity, it has also created other issues: time itself has become a more precious commodity, and people have begun feeling the effects of information overload. "We realized that the sheer volume and complexity of available information would present increasing obstacles to understanding for our customers," comments Mann, whose staff coined a descriptive term for a syndrome spawned of the information age: *infosclerosis,* a hardening or clogging of the information arteries.

In the mid-1980s, Mann explains, EPRI recognized that new approaches to delivering knowledge would be necessary if the Institute was to position itself and its members to deal with the building pressures of competition, regulatory change, and new market trends. "Those information arteries had to be unclogged for EPRI knowledge to become part of the solution for utility problems. We needed a system that would quickly and efficiently deliver the right information to the right person at the right time."

Working toward this vision, EPRI embarked on an Institute-wide effort that led to the release last May of EPRINET Version 1.0, the first production version of the system. Since then, the number of active utility users has climbed steadily, from 341 in July to more than 800 in November. At last count, over 200 utilities across the country had joined the network, along with contractors, vendors, and university organizations. In addition, virtually every EPRI employee is connected to the network.

Says Stephen Peck, director of EPRI's Environment Division and chairman of the Institute's Information Strategy Committee, "EPRINET is a central part of EPRI's information strategy of becoming more efficient in the production of knowledge, becoming more effective in delivering knowledge, and being better informed about what our utility members need."

Net benefits

To gain access to EPRINET, users install a software package on their personal computer that allows them to tap into the EPRI mainframe via modem. Other connection options are also being explored, such as linking utility host computers to the EPRI mainframe and installing EPRINET on local area networks that link multiple personal computers.

"EPRINET offers a portfolio of services from which users can select items that match their particular interests and needs," says Marguerite Pullen, EPRINET product manager. A series of on-screen menus allows even novice computer users to navigate their way through the system and find the right EPRI product, project, publication, or person.

"EPRINET users can scan the different technical division listings for updates on particular projects or to learn about new products," says Pullen. "If a user is looking for a solution to a particular problem, he or she can find out what EPRI has done on that problem and then identify the project manager with expertise in that area. Also, through the literature search feature, users can locate EPRI reports and journal articles that pertain to their problems, and they can even order the materials on-line. EPRINET can thus be a valuable tool for directly aiding in the technology transfer process."

Pullen believes EPRINET has the potential to become the electronic hub of the utility industry. "The system is not just a one-way pipeline for passing information from EPRI to its member utilities," she emphasizes. "EPRINET's electronic mail and bulletin board services let users establish a dialogue with the Institute staff. They can communicate their needs to EPRI project managers as well as communicate with their colleagues at other utilities."

For many utility employees, logging on to EPRINET has become a standard part of their daily routine. "I use it first thing in the morning, last thing in the evening, and at least a couple of times during the day," says Central and South West Services' Ed Gastineau. In addition to the news services, he regularly uses the EPRI Resource Catalogs service, which allows users to search the Institute's on-line databases and retrieve research reports and journal articles on particular topics. "Demand-side management is a hot topic around here these days," Gastineau says. "Just yesterday I plucked out 100 items on DSM. The system is also very useful in helping me identify EPRI staff people associated with a given technical area.

Electronic Tools for Technology Transfer

EPRINET™ is one member of a family of electronic communications products designed to help utility employees mine the mountain of EPRI information and extract nuggets of knowledge that can help solve problems. With its electronic mail, on-line ordering features, and topical news services, EPRINET is the general-purpose channel.

Another gateway to the Institute's publications and products is provided by ElectriGuide™. A research catalog on a compact disc—the same technology used in stereo CD players—ElectriGuide gives users rapid access to virtually all EPRI-published R&D information. The 680-megabyte capacity of this optical disc is equivalent to almost 2000 standard floppy diskettes, enough to store 250,000 pages of text; that much hard copy would occupy more than 125 feet of bookshelf space.

ElectriGuide contains three main EPRI databases, with abstracts of 7000 EPRI technical reports and descriptions of 1000 products and 23,000 research projects. In addition, software packages and the full texts of brochures, technical documents, and a collection of reports are supplied on the disc. The CD format allows for storage of more than text-based information; it can carry sound and graphics as well—including two audiovisual presentations, describing EPRI and CD–ROM technology, and over 550 technical report illustrations. ElectriGuide includes 14 color slide presentations on subjects such as demand-side management and end-use forecasting, for use by utility marketing and customer service specialists.

The contents of the disc can be quickly scanned, searched, and printed out for distribution. Its capability for compact storage and efficient printing of large documents makes ElectriGuide especially useful in utility libraries. Accessing the disc requires a personal computer equipped with a CD–ROM drive.

The next product is not an information conduit as much as a practical tool for solving specific problems. EPRIGEMS is a set of interactive computer programs that use expert systems technology to capture the results of many EPRI projects and the knowledge of staff members. Each EPRIGEMS module deals with a specific technical area, such as boiler maintenance, stress corrosion cracking, or nuclear plant life extension. Eleven modules have been released so far, and about 40 more are under development.

The EPRIGEMS system represents an entirely new approach to developing, packaging, and delivering EPRI software. Each program combines a standard user-friendly interface design with intelligent guidance to help utilities successfully apply EPRI technology in high-value situations.

The Workstation for Assisting Technology Transfer (WATT) is a specialized set of tools designed for use by METTs, managers of EPRI technology transfer. These are utility employees designated to manage the flow of EPRI information in their organizations and to create opportunities to apply EPRI-developed technology. WATT provides a tool kit of PC applications that help the METT keep track of people's interests, manage communications, and track use and benefits of EPRI products. □

EPRINET is a very helpful tool that is improving our knowledge of the Institute. Without it, effectively communicating information on EPRI activities would probably require additional staff."

Central and South West Services is working to incorporate EPRINET into its internal electronic mail network, thereby making it available throughout the utility. "We intend to use EPRINET as the backbone of our internal communications regarding research," Gastineau says.

Dave Odor, research coordinator at PSI Energy, says the EPRINET news services that offer timely information on key industry topics are very popular at his utility. Of particular value, he says, is the regularly updated information on electric and magnetic fields (EMF) contained in the EMF Forum and Hot Topics services. "We have an internal EMF working group, and EPRINET provides the front-line EMF information for that group," he says.

"The more you use it, the more you want to use it," says Bob Noberini, manager of technology transfer at Consolidated Edison. "That's because the more users become familiar with EPRINET's features, the more they appreciate the power it offers to reach into the world of EPRI R&D. It's a very useful tool for putting people in touch with information and with other people."

No experience required

EPRINET is intended to be a general-purpose, mass-audience tool. It was designed to be easy to use, even for casual computer users. "When we were developing the system," recalls Jim Mulvaney, manager of the Electronic Technology Transfer Department, "we had a sort of rallying cry: No manuals, no training. We wanted it to be usable and useful to people who had never used an on-line system before, never heard of electronic mail—or who might never have used a personal computer before. This was a formidable challenge in terms of the technology." As an example of the system's orientation to nonspecialists, Mulvaney cites EPRINET's information retrieval service, which allows users to search for publications by inputting natural English phrases rather than arcane computer commands.

"Traditionally, technical people have worked through intermediaries—librarians or other information professionals—to perform literature or technical searches," says Mulvaney. "That can be a time-consuming process, and many technical people don't want to do it unless they really have to. EPRINET puts technical end users right in the driver's seat. They can type in a query using language natural to them—such as 'What do you have on forests and acid rain?'—and quickly get a list of references to choose from. We don't expect the users to become experts in information technology; we want the technology to serve their needs as invisibly as possible—that's been the philosophy of EPRINET's design. And we're still not satisfied. We're working to make it even more convenient and easy to use."

While the "no manuals, no training" goal wasn't completely attained—there is a pocket reference to acquaint people with the procedures required to navigate through the menus—new users can log on to the network and get results without formal training. And for those occasions when they need some guidance or have a problem, on-screen help menus are available, as well as a troubleshooting guide in the pocket reference. If consulting those two resources doesn't resolve the problem, users are urged to call the EPRINET help line for quick assistance.

Project coordination

The advantages that an electronic communications system like EPRINET offers over such traditional channels as telephones and mail are especially useful in coordinating large research projects. The Institute's R&D projects typically involve many participants—EPRI staff, utility staff, and contractor staff, as well as advisory committees—and these people are often distributed all around the country, sometimes around the world. They meet periodically throughout the year, but it's still difficult to maintain communication and coordination among participants separated by distance and time zones.

"Linking a geographically dispersed team through electronic channels enhances the communications process beyond what can occur through occasional meetings and with the telephone tag that goes on," says Jim Mulvaney. "With electronic mail, a program or project manager can send a message to a hundred people as easily as to one." And instead of receiving updates on project developments at infrequent intervals—for example, when an interim or final report is published—participants can be kept informed on a continual basis via electronic communications.

A case in point is provided by a project in EPRI's Environment Division that developed a device to measure individuals' exposure to electric and magnetic fields. The device, EMDEX (for electric and magnetic field digital exposure), can be worn for extended periods to monitor and store exposure data, which can later be retrieved and analyzed.

"We had close to 60 utilities working on the EMDEX project," says program manager Stan Sussman. "There was a need for a lot of communication among participants and also a need for information on EMF-related subjects that extended beyond research issues into the legal and regulatory arenas." As the world's major supporter of EMF research, EPRI is a prime source of information on the subject for its members, and Institute staff were devoting more and more time to fielding inquiries, providing documents, and explaining concepts.

To meet this dual challenge of facilitating communications among the project participants and providing information about a rapidly evolving topic, Sussman turned to EPRINET, which at the time was in an early pilot stage. He worked with R&D analysts in the Electronic Technol-

EPRINET Services

Electronic Mail

EPRINET users can send messages to any other user on the network. Electronic mail eliminates telephone tag and makes communication more efficient: it is as easy to send a message to a hundred recipients as to one.

EPRI News

EPRI technical divisions provide regularly updated information on developments by program area. In addition, this service carries the latest news on fast-breaking issues like electric and magnetic fields, air quality, and climate change.

Resource Catalogs

Users can find reports and articles on specific subjects by using natural English phrases, and they can identify EPRI staff members with expertise in particular technical areas. Also available is a precision search that uses commands for more sophisticated and targeted information retrieval.

Special-Interest Forums

Forums provide a sort of electronic meeting place for collaborative groups—colleagues working on a project, for example, or groups of individuals sharing an interest in a particular technology. Participants receive updated information on a continual basis and can exchange ideas with their counterparts at other companies or research organizations via electronic mail and bulletin boards.

File Transfer Services

Users can send files created on their workstations (manuscripts produced on a word processor, for example) to other EPRINET participants, and they can receive and view files sent to them. They can also transfer any information available on EPRINET to their workstation for local printing or storage.

EPRI Calendar of Events

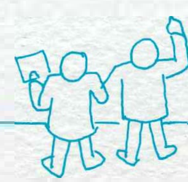
Dates, locations, and descriptions of upcoming events—including meetings, conferences, courses, and workshops—are listed by sponsoring EPRI division.

EPRINET Directory

The directory lists all EPRINET users by company, as well as the members of each special-interest group.

Help Desk

Customers can call the help desk hot line (415-855-1000) to obtain expert assistance from EPRINET user support analysts. The help desk is staffed from 6:30 a.m. to 6:00 p.m. (PST) Monday through Friday.



ogy Transfer Department to develop a special-interest forum, the EMF Forum, which provided a set of services to meet the needs of the project participants. These were electronic mail, news, EMF information retrieval, an electronic bulletin board that allowed participants to post messages or inquiries for their colleagues, and a service called Ask EMF, through which users could address questions on the topic and receive expert answers.

The EMF Forum soon proved its value. The majority of participants surveyed described it as very useful and as having a positive impact on the EMDEX project. Participants cited benefits that included timely access to fast-breaking news, convenient access to EPRI staff and project colleagues, and time saved in sending messages and information. Electronic mail alone proved to be a big benefit. As one engineer working on the project noted, "I probably wouldn't feel as free about contacting the EPRI project manager if I had to write letters or call him. But with electronic mail you feel as if the office door is always open."

Building on the foundation provided by the EMF Forum, more EPRI program and project managers are bringing their work groups onto EPRINET. Some of them are organizing special-interest forums that, like the EMF Forum, have customized menus and services. Others are simply signing up their task forces, user groups, committees, and contractors to take advantage of the general network services.

Bill Sun, a program manager in EPRI's Nuclear Power Division, was quick to recognize the potential of EPRINET for improving communications and information exchange in a particular utility community—those interested in the rapidly advancing field of artificial intelligence and expert systems. Sun manages the Knowledge Based Technology Applications Center, an Institute-sponsored technology transfer organization at Syracuse University. KBTAC's mission is to help member utilities develop and test expert systems and bring them into various aspects of utility business, including power plant operations, maintenance, and engineering. "One of KBTAC's functions is that of an information clearinghouse," says Sun. "It helps utility staff learn which companies are involved in knowledge-based systems, for example, or what commercial tools are available for the IBM PC that enable a utility user to build rule-based systems. When EPRINET came along, we immediately realized that it would be a good vehicle to improve the productivity and add value to this clearinghouse function."

Under Sun's sponsorship, the KBTAC Forum came on-line last November with a full array of services: mail, news, an Ask KBTAC hotline, an electronic bulletin board, and access to the center's databases. These databases contain information on EPRI-developed and commercially available expert systems tools, on utility expert systems development, and on the areas of expertise of the KBTAC staff.

"The forum allows member utilities to find out what EPRI and the industry are doing with expert systems," says Sun. "They can quickly and efficiently get practical answers to their questions or connect with an expert. Moreover, the forum provides a vehicle by which utility users can connect with each other and share information on their expert systems applications."

Such interutility communication is on the rise, as users warm up to the idea of electronic networking. As Con Edison's Bob Noberini notes, "If you can exchange information with people in other companies who are working on the same problem, it can save you from reinventing the wheel in your own company—and thus help you make more effective use of your research dollars."

Stocking the shelves

"In describing EPRINET we often use the analogy of a shopping center," says Jim Mulvaney. "A shopping center has certain anchor tenants, like Macy's and Sears, that are the big draws. Once those anchor tenants are installed, then all sorts of specialty shops can flourish that couldn't flourish on their own, without the draw provided by the anchor tenants. Similarly, EPRINET has core services—electronic mail, information retrieval, and general news services. Special-interest services and forums are the specialty shops. We've been working to get each EPRI technical division fully represented on the network, and we'll be there soon. Then it's a matter of continually stocking the shelves with new merchandise."

Much of that merchandise is already in place. For example, EPRI's Customer Systems Division has a full-feature service that includes news updates by program area describing each month's program highlights; announcements of upcoming events; and a service called Comm Chronicles, through which users can order the division's publications, videos, and software products.

"We've tried to put together a one-stop shop," says Greg Lamb, the division's technology transfer administrator. "Users can read about what's happening in the division, find out what publications and products are available, and then order them on-line."

Three other EPRI technical divisions—Electrical Systems, Environment, and Generation and Storage—joined the network last year, each offering news services in its R&D program areas. By the first quarter of 1991, each of the Institute's technical divisions will be represented on the network, Mulvaney predicts.

Continuing challenges

The EPRINET product team welcomes feedback and suggestions from users that can help them provide the features and services customers want. Such information was a key ingredient in bringing the system through its early pilot stages to the first production version, which is now in use. "We made significant changes to

I am continually amazed at the amount of information available.

—Tyrone Blackburn, Portland General Electric

Good communication tool with time zone differences.

—Douglas Anderson, ARINC Research Corp.

I found the system to be one of the easiest I've encountered for file transfers.

—Alan Wickert, Public Service Electric & Gas

I have been using EPRINET for about 18 months and I think it is great. I use it mostly for sending messages . . . and for keeping key people in my company up to date on EMF matters appearing in Hot Topics. . . . I have also found EPRINET especially handy for ordering EPRI publications and researching the literature on topics of interest.

—B. E. Newton, Central Illinois Public Service

This makes ordering reports (and finding them) very easy. Thanks.

—Dick Paulk, Public Service Co. of New Mexico

Very easy to use and understand . . . I actually look forward to using EPRINET every day. . . . Fantastic support . . . thanks!

—Shannon Jenne, Idaho Power

It is helping me to do my job better, faster.

—Irvin Chronister, Kansas City Power & Light

EPRINET has been a major step forward in information transfer.

—G. Palomino, Salt River Project

EPRI is to be commended for the emerging application of advanced technology to the business of disseminating EPRI results and providing technical communications services for the membership.

—James Jura, Administrator, Bonneville Power Administration

Speedy access to EPRI's wealth of data.

—John Ellington, Duke Power

the product, based on feedback from users, that have made EPRINET easier to use," says Margie Pullen.

Still, Pullen and others who have worked to make EPRINET possible are the first to admit that the system has a way to go before it reaches its full potential. The EPRINET team continues to face challenges: marketing the system to utilities, installing the system on different computer systems, and managing the evolution into what is intended to be the premier electronic communications tool for the electric utility industry.

The first challenge is an echo of the larger challenge the Institute faces—that of getting its products into the hands of utility end users. "Probably the biggest barrier for us to overcome is just making the utility community aware that this product exists," says Pullen. To this end, EPRINET marketing teams have been visiting utilities to describe the network and demonstrate how it can help employees find solutions to their business problems. "By the end of 1990 we'd visited nearly 60 utilities," she says, "and as a result, we've seen very good growth in the number of users. As in any marketing program, this product is sold to one customer at a time." When a customer signs up to make the EPRINET connection, he or she is sent a startup package that includes the system software and the system documentation. This package is available for $295—a price tag that covers the Institute's commercial license fees.

In the most common type of connection, a user equipped with a personal computer and modem just installs the EPRINET software package on his or her PC. This installation procedure is highly automated, takes about 15 minutes, and usually goes off without a hitch.

But making elaborate customer hookups can be more problematic. The Information Technology Division can hook EPRINET directly to a utility's mainframe computer—a host-to-host connection—and has been experimenting with local area network (LAN) connections. These types of installation are gaining favor because they give many users access to EPRINET without each one's having to have a modem. LAN connections, in particular, are not simple to accomplish, owing to the maddening lack of standardization in computer hardware. "Establishing LAN connections is challenging," says Ron Kohl, manager of system development for EPRINET. "Because no two LANs are alike, it requires some special hardware and software tailoring on the customer LAN to fit EPRINET as seamlessly as possible into the utility's system."

Future directions

Even as EPRINET Version 1.0 is being put to work at utilities, the development team is striving to improve the system. This first version, while functional, lacks some of the features that users expect from their personal computers. Those accustomed to working on advanced PCs with a lightning-quick response time and a state-of-the-art graphic interface have to adjust to the "mainframe look and feel" of EPRINET—it's like switching from a sports car to a delivery truck. When connected to the network, the user's PC functions as a so-called dumb terminal—all the computational work is being done by the EPRI mainframe, not the PC. User commands thus have to travel over telephone lines to Palo Alto, and the mainframe's response has to return to the user's computer before showing up on the screen. This lag in response time has been one of the main criticisms of EPRINET.

The development team aims to eliminate such drawbacks in subsequent versions of the system. "We've already improved the response time by improving telecommunications and adding fast-path commands," says Pullen. "These allow users to navigate more quickly through the menus by jumping directly to where they want to go." But the real improvement will come with Version 2.0, which is scheduled to be available at the end of 1991. This version will use what's called a coprocessing environment, meaning that the user's PC will be shouldering a share of the computational work from the EPRI mainframe. This will speed response time and will also accommodate the kind of graphic interface—with snappy features like windows—that some PC users have grown accustomed to.

But for now, the delivery truck gets the job done. Comments from the user community indicate that most customers are finding the system a useful and valuable tool for extracting nuggets of knowledge from the mountain of EPRI's accumulated information and expertise. "I think EPRINET helps make membership in EPRI more cost-effective," says Con Edison's Bob Noberini. "When a person needs a specific piece of information or a solution to a specific problem, it's daunting, to say the least, to have to search through volumes of printed material. It's much easier to get on-line, ask a question, and get an answer." And after using EPRINET's information retrieval service, Kam Joshi of TU Electric says, "I just found in three minutes what has taken several weeks to find in the past."

Comments like these indicate that EPRINET is helping the Institute bypass infosclerosis and deliver the right information to the right people at the right time. ■

This article was written by David Boutacoff. Background information was provided by Marina Mann, Jim Mulvaney, and Ron Kohl, Information Technology Division, and Marguerite Pullen and Celia Weaver, Membership Division.

UPDATE ON

From instant sensation to virtual pariah, "cold fusion" has had a stormy history since two University of Utah researchers first announced its discovery in March 1989. Research into this mysterious phenomenon has been plagued both by technical difficulties in replicating experimental results and by sometimes bitter controversy over scientific standards and personal credibility. Now, in a somewhat calmer atmosphere, significant progress is being made through experiments that are reproducible over long periods of time and under a variety of conditions. These experiments indicate that nuclear reactions may indeed occur at room temperature in a crystal lattice in ways not understood before.

"It's time we stopped calling these reactions cold fusion," says David Worledge, EPRI coordinator of research in this area. "There is now good evidence that cold nuclear reactions of some sort are taking place, but also growing indications that they aren't conventional deuterium-deuterium fusion, as first assumed. Also, the cold nuclear reactions inferred from the neutrons that have been detected are not numerous enough to be responsible for the excess heat production still being reported in some experiments."

In their original work, University of Utah scientists Martin Fleischmann and Stanley Pons used a simple laboratory apparatus consisting of a palladium rod surrounded by a platinum coil and immersed in heavy water. They reported that when a small electric current was applied to the cells, deuterium nuclei from the heavy water were driven into the palladium rod, where they were held in the metal lattice and apparently fused, producing 4 watts of heat for each watt of electric power supplied. At about the same time, Steven Jones of Brigham Young University reported finding neutrons emitted from a similar apparatus—indicating the presence of nuclear reactions—but the neutron production rate was a thousand billion times lower than would have been expected if the heat reported by Fleischmann and Pons was produced by conventional deuterium-deuterium fusion.

Some of the latest experimental results related to cold nuclear reactions were presented at an international workshop in October at Brigham Young University, sponsored by EPRI, the U.S. Department of Energy, and BYU. According to David Worledge, the feeling at the workshop was that this area of research has matured considerably, through carefully controlled experiments that are becoming increasingly reproducible. Significantly, a majority of the 62 papers presented at the workshop showed results that support the existence of cold nuclear reactions. But not enough information has yet been provided to identify the nature of the reactions or to explain the continuing discrepancy between observed levels of neutron emissions and the still-tenuous reports of excess heat production.

Reproducible experiments

The closest anyone has come to providing scientific "proof" of cold nuclear reactions, in terms of carefully controlled experiments that are reproducible, is the work of Howard Menlove of Los Alamos National Laboratory, which is partially supported by EPRI. Using only small, loose chips of titanium alloy in a steel bottle filled with deuterium gas—no current, no heavy water—Menlove reliably produces bursts of neutrons by first immersing the bottle in liquid nitrogen and then letting it warm slowly to room temperature. Neutron emissions usually begin as the titanium passes roughly the –50°C mark and continue up to room temperature. Menlove has successfully reproduced the experiments inside a tunnel at Los Alamos and in a deep mine in Colorado, where background radiation due to cosmic rays is substantially reduced. The results have also been confirmed by Steven Jones of BYU, who uses a similar apparatus but a different type of neutron detector.

Other charged particles—possibly tritium ions—have been detected in the course of EPRI-supported work by Edward Cecil of the Colorado School of Mines. Using the same titanium alloy as Menlove, Cecil heats individual pieces of metal in a deuterium atmosphere, cools the sample and transfers it to a vacuum chamber, and places it on a cold mount near a particle detector. After lowering and then raising the temperature while passing a current through the sample, Cecil has measured bursts of charged particles at rates as high as 1000 counts per second. Although these experiments were about 50% reproducible over a period of two months in their original configuration, Cecil has been unable to find particle bursts after making substantial changes in the apparatus.

Further pursuing the approach first used by Fleischmann and Pons, Kevin Wolf of Texas A&M University has conducted reproducible experiments in which he observed neutrons in electrolytic cells containing palladium samples. The credibility of this EPRI-sponsored work was enhanced when Wolf continued to detect neutrons after moving his cells to the deep Colorado mine and using Menlove's neutron detector.

A variety of other experiments reported at the recent BYU meeting have had varying degrees of reproducibility in terms of detecting radiation from cold nuclear reactions. A second Los Alamos group has observed neutrons and tritium by running an electric current through a device made of alternate silicon and palladium disks. Soviet scientists report finding emissions of neutrons and tritium from both titanium deuteride and palladium deuteride samples that were heated in a vacuum from low temperature. And a group at the Chinese Institute of Atomic Energy, using an apparatus similar to Menlove's, verified his results. Other experiments continue to show negative results, however, and much more work will be needed for any of these experiments to be considered definitive.

Where's the heat?

Although much of the intense early interest in so-called cold fusion was generated by its prospect as a new source of useful energy, experiments on heat production have proved far more difficult to replicate or interpret than those on radiation. Because of this difficulty, the BYU conference concentrated exclusively on nuclear effects. According to David Worledge, most of the early observations of large excess heat production "simply went away when people did their calorimetry more carefully." With one exception, reports of heat measurements now circulating around the scientific community show only a few percent greater heat output than input, and many uncertainties remain.

The exception is work at the University of Hawaii, involving only two experiments—one using titanium, which reportedly produced 60% excess power, and one using palladium, with 600% excess power. EPRI has initiated collaborative work with BYU to search for neutron emissions during heat production at the Hawaii facility. Meanwhile, these data must be considered very preliminary.

Tentative interpretations

If either the tritium emissions or the excess heat observations are definitively confirmed, says Worledge, the cold nuclear reactions could not be simple deuterium-deuterium fusion. The tentatively observed tritium particles have five times the energy that could be accounted for by a D + D reaction. Generating the reported quantity of heat from D + D reactions would have created dangerous levels of neutron radiation in the laboratory, which certainly have not been observed.

One possibility is that the neutrons and other charged particles are occasional, secondary products of cold nuclear reactions. There would then be the possibility that other, undetected reactions are generating most of the energy, which is being absorbed directly by the atomic lattice of the metal samples. The problem with this explanation is that it is hard to imagine how so much energy produced in a tiny area could be dissipated.

"Transferring energy from the nuclear reactions to the lattice is equivalent to having a thief try to snatch a purse while traveling on some super rocket at millions of miles per hour," says Worledge. "Grabbing the purse would utterly destroy both it and the surroundings. In a similar way, one would expect to see significant disruption of the lattice and large fluxes of X rays from sites of cold nuclear reactions, and these have not been observed."

Finally, tentative interpretation of the charged-particle data indicates that the cold nuclear reactions are taking place at specific active sites in the metal samples and that the size of the sites is on the order of a few micrometers. Within these sites, power generation densities appear to be quite high—about 1000 watts per cubic centimeter. The implication of this discovery, if it is borne out, is that the ability to put cold nuclear reactions to practical use will depend on whether the number of active sites can be increased substantially and how long they can be sustained before the metal is destroyed.

Future plans

So far, EPRI has spent about $2 million on research related to cold nuclear reactions. By providing continuity of funding and carefully coordinating work with other research sponsors, the Institute has emerged as a key player in the field. In 1991, EPRI expects to continue funding—at a somewhat reduced level—with particular emphasis on studying the spectra of neutrons, reproducing the neutron experiments in a specially equipped Japanese laboratory located in a deep mine, and creating a definitive experiment for identifying charged particles. In addition, considerable effort will be made to improve the reproducibility of heat production and to establish a link between cold nuclear reactions and the excess heat.

"Establishing this link is critical if the field of cold nuclear reactions is to become something other than a scientific curiosity," says Worledge. "However things turn out, though, I believe the Institute has helped bring a potentially important scientific discovery to the brink of definitive analysis." ■

This article was written by John Douglas, science writer. Background information was provided by David Worledge, Nuclear Power Division.

TECH TRANSFER NEWS

TMI-2 Recovery History Published

The reactor accident at Unit 2 of Three Mile Island began at 4:01 a.m. on March 28, 1979. Thirty days later, cold shutdown and natural circulation were achieved. More than two years passed before a video camera could gain a view inside the ruined reactor. The defueling operation commenced on October 30, 1985—over five years and seven months after the accident. The defueling process took nearly four and a half more years. It was completed in April 1990.

Innovation and flexibility were key features of the cleanup. Enhancement or design of 30 mechanical systems was necessary to achieve stability in the reactor core. Dozens of other systems were also required, for functions ranging from personnel support to data acquisition to waste management. Four pioneer robotic vehicles cleaned the containment basement. Decontamination was also conducted in the auxiliary building and on the operating levels of the containment. A defueling system was designed to convey fuel and reactor debris from the reactor vessel to canisters, which were then placed in special transportation casks for shipping to the Idaho National Engineering Laboratory. For every option taken in these actions, many were considered and many discarded.

In 1988 Ray Lambert, the EPRI TMI-2 program manager, became concerned that a valuable source of information was being lost as some of the key people began to leave the TMI-2 site. Lambert and others involved in the cleanup feared that the memory of how technical decisions had been made would be lost. This concern prompted EPRI to contract with Grove Engineering, a company that had been involved in the cleanup activities since 1979, to record the recovery history. The job, says Lambert, was to "make sure that the lessons learned were documented. In addition, EPRI wanted to ensure that the technologies evolving out of TMI-2 were packaged in such a way that they could be transmitted to other utilities for their use."

The result is *The Cleanup of Three Mile Island Unit 2: A Technical History, 1979 to 1990* (NP-6931). To compile the history, Grove conducted hundreds of hours of personal interviews with people close to the cleanup effort. Over the two-year project period, drafts were reviewed by GPU Nuclear, the plant operator, and by the Department of Energy and the Nuclear Regulatory Commission. "We had amazing support at very high management levels," says Lambert. Key people "took the time to go through and really read that document."

In addition to recording the technical history, the report explores discarded options and explains the logic applied in reaching the choices. For example, the defueling options included five conventional alternatives and one innovative strategy. Sketches of each are set forth, and the determining factors discussed.

Each of the eight chapters is an independent unit. Ten appendixes supplement the text; they include subsystem descriptions, a 27-page chronology of the cleanup events, and a transcript of the first postaccident entry into the containment. Lambert explains that the report is organized to allow readers to enter into the areas of specific interest to them—"with plenty of graphics that help lead them through the story."

According to Lambert, the TMI-2 technical history "provides an appreciation for the complexity and severity of such an accident and the challenge that technical managers face in dealing with these kinds of issues." The nuclear plant manager who understands this 10-year process of technical decisions at TMI-2 gains an increased sensitivity, he says. The report also can provide insight into events of much lesser magnitude than the TMI-2 accident. For example, at least one utility is using the report to introduce staff to the cleanup consequences for any fuel damage scenario. Lambert concludes, "The report reveals the dramatic and startling level of effort necessary to effect a recovery; it paints a picture that forcefully underscores the importance of avoiding these kinds of accidents." ■ *EPRI Contact: Ray Lambert, (415) 855-2788*

Power-TEC Associates

There are times when transferring the results of EPRI research to field application requires more resources than can be provided by an R&D project's allotment of manpower and funding. Under a new service intended to augment the Institute's technology transfer activities, EPRI is assigning technical staff members to help utilities solve power plant problems and improve operation and maintenance programs. The service will be carried out by Power-TEC Associates, a group of EPRI managers who will provide leadership and coordination for projects directed at solving utility problems.

"Power-TEC Associates provides a unique service for transferring EPRI research results to field applications," says George Touchton, program manager for fossil plant operations in EPRI's Generation and Storage Division. The idea for forming Power-TEC Associates, he explains, grew out of the Institute's billable services policy. This policy entitles each EPRI member utility up to five days of direct technology transfer work from the

Institute on a specific problem; beyond that, members can purchase additional EPRI staff time. As the demand for such services has grown, so has the need for more coordination of the projects.

Tony Armor, acting director for fossil power plants in the Generation and Storage Division, explains: "We saw an opportunity, within the guidelines of the billable services policy, to extend technology transfer by putting in place a team to help deliver EPRI products, intellectual property, and expertise to our members. Very often EPRI project managers have unique expertise acquired through their involvement in the development of products. Working in concert with our traditional allies—such as architect/engineers and suppliers—we can bring that expertise to bear on complex utility problems to enhance the services we've traditionally provided to our members."

An example of the type of project that Power-TEC might tackle, Touchton says, is that of a utility experiencing problems with feedpump availability. "The company may require root cause analysis, design alternative analysis or upgrade alternative analysis, and monitoring and diagnostic expertise. We would put together a team of EPRI experts from different technical programs and propose that team to work with suppliers and architect/engineers to address the overall problem at the utility." Depending on the nature of the problem, staff from any of the Institute's technical divisions might be called on. The makeup and composition of the team will be driven by demand, according to Touchton and Armor.

While Institute R&D products should be applicable in most cases, Power-TEC is not geared exclusively to applying EPRI products, says Touchton. "We recognize that no matter how comprehensive an R&D program we might have, not every EPRI product is going to be exactly applicable to every situation. The problem's resolution may require a combination of products, and in some cases an outside product may be the best option for the utility's needs."

Fees paid to the EPRI personnel working on these projects are fed back into their R&D programs so as not to detract from the management or budgets of those programs. "EPRI has been working much more closely with our members," Touchton goes on, "responding to their changing needs and making certain that our R&D products are fully utilized. Power-TEC Associates provides a new mechanism for serving our members better while preserving our R&D programs." ■ *EPRI Contacts: George Touchton, (415) 855-8935, and Tony Armor, (415) 855-2961*

Video Cameras at Nuclear Plants

Nuclear power plants have long employed closed-circuit television in a few applications, but early setups were available only as engineering-intensive, turnkey systems. At least three factors have significantly expanded the prospects for in-plant video over the past decade: the Three Mile Island cleanup efforts led to innovative new applications and configurations for video cameras; prices for video systems have continued to fall; and advances in technology have improved system performance.

A recent EPRI survey has shown that the modest cost of low-end systems can now be easily justified by high benefit ratios in a number of applications. And once installed, camera systems may spin off unforeseen operating improvements. Today a few utilities are encouraging technicians, supervisors, and engineers to experiment with video technology to gain direct benefits and create opportunities to improve productivity and reduce costs.

The widest application of video technology is in dose reduction for health physics technicians. At the Oyster Creek plant in Forked River, New Jersey, for instance, the engineering department documented significant savings (6.4 person-rems) in exposure of health physics technicians over the course of a 13-day repair project. The second most useful application is in work crew supervision. Carolina Power & Light, for example, reports saving between 18 and 22 person-rems per year at its Brunswick plant by using voice-and-video supervision of operation and maintenance crews. A third important application is in general area surveillance and inspection.

The lowered exposures that result from these applications are typically valued at $5000 per person-rem, according to one source in the study. Explains EPRI project manager John O'Brien, "Workers who get more than their quarterly allotment of exposure may have to be replaced. But the cost of exposure is not measured just in labor costs." Outages may become longer as well, says O'Brien, as work crews are rotated to complete a job. Longer outages, of course, mean higher outage costs.

Spin-off applications of video technology include video previews of work sites, improved crew communications, and enhanced working visibility for crane operators. Florida Power & Light has even created a plant television network to inform and educate employees continuously.

The results of the EPRI study are included in *Video Camera Use at Nuclear Power Plants: Tools for Increasing Productivity and Reducing Radiation Exposure* (NP-6882). The report provides practical guidance in the application of video cameras to plant requirements—from explanations of how equipment operates, to detailed descriptions of actual plant applications, to lists of contacts at utilities that are successfully using the technology. The range of questions answered includes how to determine objectives in making program plans, how to acquire inexpensive camera systems, and how to implement video systems. ■ *EPRI Contact: John O'Brien, (415) 855-2214*

Probabilistic Analysis and Application

Human Reliability Assessment

by Avtar Singh, Nuclear Power Division, and Tim Martin, Pacific Gas and Electric Company

ABSTRACT *To help utilities assess the impact of human actions on plant risk and understand the causes of human error, EPRI initiated a human reliability research program in 1982. Under the guidance of utility advisory and steering groups, this work concentrates on providing such products as human reliability analysis guidelines, quantification methods, and operator performance data from full-scale plant simulators. These products are being applied by many utilities to evaluate plant risks and identify vulnerabilities, if any, as part of the individual plant examination effort requested by the NRC. Program results have also been useful to some utilities in enhancing the consistency and reliability of control room crew performance.*

The Three Mile Island and Chernobyl experiences have shown that human actions can play a key role in both causing and mitigating accidents at nuclear power plants. Reviews of various probabilistic risk assessment (PRA) studies performed over the past several years have pointed to the need to strengthen the methodology for incorporating and accounting for human impact. In November 1989, the Nuclear Regulatory Commission issued a generic letter requesting each nuclear power plant licensee to perform an individual plant examination (IPE) for severe-accident vulnerabilities. The NRC subsequently published guidelines for utility IPE submittals and listed PRA as one of the accepted methods. Most utilities have recently initiated their IPE efforts, which has heightened the need for a consistent and validated human reliability analysis (HRA) methodology for the proper integration of human impact in probabilistic risk assessments.

Issues in human reliability analysis

Most methods for quantifying the probability of human error were developed during the last decade. Because of a serious lack of prototypical nuclear plant data, these methods rely heavily on expert judgment or analytical techniques. In some cases, a limited validation was performed by using data from human activities not directly related to nuclear plant operation. The available data were mostly from simple, routine activities performed by individuals. These data lacked the key elements of team behavior exhibited by a nuclear plant crew and the elements of dynamic behavior related to detection, diagnosis, and decision making following an accident.

An international benchmark exercise to assess the consistency and variability of results obtained by several existing HRA methods was recently completed. In this exercise, experts from many countries, including the United States, used the available methods to calculate human error probabilities for a defined set of benchmark problems. To no one's surprise, for some human actions the predictions varied by up to three orders of magnitude. Another key finding was that a greater consistency in results was achieved when the same expert applied different methods than when different experts applied the same method. This confirmed the dependency of these methods on the individual analyst's judgment and pointed out a lack of objectivity and realism in the methods.

Other HRA issues include how to integrate plant system logic models and analyses of human actions and how to treat dependencies between multiple human actions when operators, following procedures, perform a series of actions. Traditionally, human reliability analyses have been performed ad hoc: the plant system logic models were developed first, and then the impact of key human actions (identified on the basis of expert judgment) was added to the system models for overall risk evaluation. This approach did not appropriately account for the impact of human actions. Also, because of the complexity of the analysis, the interdependency of multiple human actions has generally been ignored in past PRAs. Recently an NRC peer review committee composed of nine experts from around the world (including EPRI's John Taylor, vice president, Nuclear Power Division) identified areas where further research is needed to reduce uncertainty in human reliability models and to address the impact of "errors of commission," in which operators may initiate events.

Practical IPE issues—such as how to organize a team, how to carry out an examination in a cost-effective manner, and how to utilize the insights gained—also must be addressed. In particular the NRC guidelines (NUREG-1335) call attention to how the results of these studies will be applied to the "operation and daily activities of the plant . . . to facilitate integration of knowledge gained from the examination into operating procedures and training programs."

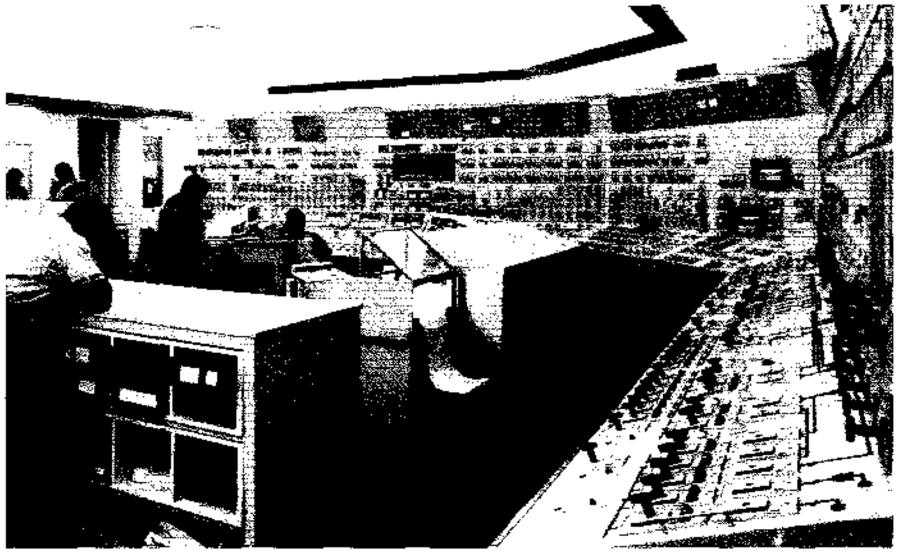
EPRI efforts

EPRI's human reliability research projects are designed to address the issues described above. Early in 1984, EPRI developed the Systematic Human Action Reliability Procedure (SHARP) to provide an organized framework for the analysis of human reliability in PRAs. SHARP was widely accepted by the industry (including the Institute of Electrical and Electronics Engineers and the NRC) as an acceptable framework for performing HRAs. EPRI has been developing an enhanced version (SHARP1) that provides additional guidance on the integration of PRA system and human action logic models and on the treatment of interdependencies among multiple human actions. The enhanced framework will also provide a comparison of the strengths and weaknesses of various available methods for quantifying the probability of human error.

Also in 1984, on the basis of the limited data then available, EPRI developed the Human Cognitive Reliability Model for predicting dynamic operator behavior during the detection, diagnosis, and decision-making phase following an accident, when the crew is using emergency operating procedures. Like SHARP, this model was a major milestone in the development of state-of-the-art HRA quantification techniques; however, the question of its validity in assessing plant crew reliability still remained to be answered.

Under the sponsorship of Commonwealth Edison, the Human Cognitive Reliability Model was used to classify and organize operator performance data collected at the LaSalle plant simulator. As a result of this application and of the positive experience of Electricité de France (EdF) in an independent simulator experimental program, EPRI initiated a project to collect data on operator performance from full-scale plant simulators (Figure 1).

Figure 1 In EPRI's operator reliability experiments, data on the performance of nuclear plant control room crews are collected in connection with training and requalification sessions in full-scale plant simulators like the one shown here. These data are useful for determining the impact of human actions on plant risk and for identifying procedural and other modifications to enhance crew performance.



Called the operator reliability experiments (ORE) project, this effort was jointly sponsored by EPRI and six U.S. utilities—Commonwealth Edison, Duke Power, Pacific Gas and Electric, Pennsylvania Power & Light, Philadelphia Electric, and Wisconsin Public Service. As cosponsors, these utilities typically made available their full-scale plant simulators and operating crews for data collection (usually in conjunction with already scheduled operator requalification sessions). The project involved the collaboration of utility operations, training, and PRA staffs. The data set was further expanded when Taiwan Power joined the EPRI project and undertook data collection at its Maanshan plant simulator in mid-1989. The EPRI and EdF programs were closely coordinated via active collaborative exchange between the two organizations. Other organizations associated with the project advisory group were the Institute of Nuclear Power Operations and General Public Utilities.

As a result of the ORE project, there is now an extensive database on operator performance, with more than 1300 data points for multiple crews from seven different plant simulators. Various applications of these data, described below, point to the value of plant-specific simulator data collection by individual utilities for PRA and risk management uses. To assist utilities in making the data collection process cost-effective and less manpower-oriented, EPRI is developing a software system called Operator Reliability Assessment Systems (OPERAS). The software will make it possible to collect operator performance data directly from the simulator by means of a personal computer, thus minimizing the need for utility resources for manual data collection. EPRI has recently initiated a project to study the causes of errors of commission and to investigate possible approaches to modeling and quantifying their probability. Data from real plant events as well as from simulators will be analyzed to support this study.

The products of EPRI's human reliability program, including those under development, are listed on page 40.

EPRI product applications

Several utilities have used the original SHARP framework and the Human Cognitive Reliability Model in performing plant-specific PRAs.

Available Products

Systematic Human Action Reliability Procedure: SHARP (NP-3583)

Benchmark of SHARP (NP-5546)

SHARP1 Methodology for Human Reliability Analysis (NP-7183-SL)

A Human Reliability Analysis Approach Using Measurements for Individual Plant Examination (NP-6560-L)

Operator Reliability Experiments Using Power Plant Simulators (NP-6937, Vols. 1–3)

Operator Reliability Experiments at the Maanshan Nuclear Power Plant (NP-6951-L)

Products Under Development

OPERAS Software and Users Manuals

Modeling and Treatment of Recovery Actions in PRA/HRA

Error Analysis With Emphasis on Errors of Commission

HRA During Alternative-Mode PRAs

Guidelines for HRA During Interface Systems LOCAs

The operator reliability data have been used to modify the original Human Cognitive Reliability Model—which featured a skill-, rule-, and knowledge-based classification of human actions—to a procedure-based cue-response classification. This improved approach allows for the explicit integration of the impact of operating procedures into PRAs. Insights gained from the data are being used by EPRI to provide additional guidance to utility analysts on the detailed logic modeling of human actions and its integration with system logic models in the SHARP1 framework. As a result of these efforts, SHARP1 and the modified Human Cognitive Reliability Model provide state-of-the-art tools for use in plant-specific PRAs undertaken by utilities. The applicability of these products is now being demonstrated by Cleveland Electric and Texas Utilities for the Perry and Comanche Peak nuclear plant PRAs, respectively, and by EPRI's Advanced Light Water Reactor Program.

The EPRI research products have important applications in other, non-PRA areas as well. Direct measurements and observations of crew performance in key accident scenarios in simulator exercises provide insights regarding the consistency and reliability of plant operating crews. For example, crew performance has been found to be affected by such factors as the man-machine interface, operating procedures, training, and control room design. These factors can influence operator actions, such as the number and impact of errors made by crews. Posttest interviews with the crews help clarify the reasons for their specific actions and response characteristics. Their insights can be used in making enhancements that lead to increased crew reliability. The following examples demonstrate the benefits of this data collection and analysis approach—the ORE approach.

One application occurred in connection with EPRI's development of the BWR Emergency Operating Procedures Tracking System (EOPTS), an on-line expert system that provides a symptom-based computerized approach for assessing plant status and implementing emergency operating procedures during critical stages of an emergency. An evaluation of the system was carried out at Taiwan Power's Kuosheng plant simulator by using the ORE approach. The performance of plant crews who used a flowchart version of the procedures was compared with that of crews who used EOPTS. The results demonstrated that crews using EOPTS are more consistent in their actions, commit fewer errors, and are more successful in recovering from inadvertent errors. The ORE approach proved to be a powerful tool for the objective and quantitative evaluation of the impact of operator aids on crew performance.

Another type of application involves the verification and validation of operating procedures. The data recorded during simulator exercises may point to a deficiency in procedures, such as a lack of clarity, missing steps, or inaccurate logic. The ORE approach, with its detailed analysis of simulator data and crew feedback, can assist the plant staff in identifying procedural enhancements that can lead to more-appropriate crew response and increased reliability.

Pacific Gas and Electric (PG&E) used the approach to identify potential enhancements to its procedures for determining safety valve status. Simulator data indicated that plant crews were having more difficulty in diagnosing a stuck-open safety valve than a stuck-open relief valve. An analysis of crew performance revealed that the safety valve status check was not explicitly required in the procedure logic. Once this check was added, crew performance became consistent with that in determining relief valve status. PG&E has also used this approach in evaluating procedures concerning the tripping of a residual heat removal pump shortly after safety injection so as to prevent dead-heading of the other RHR pump.

Simulator data can also help identify the need for specific changes in control room design, human factors, or the man-machine interface to enhance the reliability and consistency of crew performance. Further, if such changes are implemented in the simulator, the ORE approach can confirm whether the proposed change actually leads to improved crew performance. In one such application, PG&E found that a particular control board configuration resulted in operator uncertainty and hesitation in an anticipated transient without scram (ATWS) action. The controls will be modified to eliminate this observed effect.

Another application addresses the consistency of crew performance in a set of dominant risk scenarios, a key factor affecting crew reliability. Consistency can be measured in terms of the variability of one crew's performance characteristics or in terms of the numbers and types of errors made by different crews at a plant. A historical record of these measurements (from year to year or from one requalification session to the next) can provide the plant training staff with a progress report on the reliability of crew performance. In cases where an apparent inconsistency is seen, it may be prudent to take further action to determine and eliminate the cause of the inconsistency.

For example, during one simulator exercise scenario, performance data on 11 crews were collected. An analysis of the data indicated that 10 of the crews showed performance characteristics within the expected range of scatter. The abnormally inconsistent performance of one crew in this scenario prompted further analysis of the data, which indicated the cause to be a lack of teamwork and communication among the crew members. Giving feedback to the crew and raising their awareness of this deficiency improved their consistency relative to the other crews.

One output of the EPRI OPERAS software for automatic simulator data collection is especially useful in analyzing crew consistency: a chronological listing of significant actions identified by the instructor. PG&E has found this output to be valuable for various purposes—for example, for verifying the complete and proper isolation of a steam generator following a tube rupture. The listing of a single crew's actions is used in the post-scenario interviews, and listings for several crews responding to similar events are compared to identify any common problems.

HRA research benefits

The products of EPRI's human reliability research are designed to provide support to nuclear utilities in their IPE and risk management efforts. The measurement-based HRA methodologies and the database generated by EPRI serve as a technical basis to substantiate the validity of the human reliability techniques used by utilities in their IPEs. Application of the EPRI products will help minimize utility effort and conserve utility resources in achieving a greater degree of confidence and regulatory acceptance.

In addition to enhancing the accuracy and credibility of risk quantification, the EPRI research results provide a direct means of understanding the basic causes of the potential for human error. Achieving such an understanding may help reduce human error and enhance the reliability of plant crews, which translates into increased plant availability and reduced risk in plant operation.

System Reliability Engineering

RAPID for Engineering Analysis and O&M Support

by Boyer Chu, Nuclear Power Division

RAPID—Reliability Analysis Program With In-plant Data—is a software system that combines key features of plant information management systems, modern computer technology and techniques for system reliability analysis (SRA) and probabilistic risk assessment (PRA). RAPID provides utility technical staff with an automated environment for performing risk-based and reliability-based engineering evaluations. It supports both off-line engineering analyses and on-line operation and maintenance (O&M) applications.

RAPID's off-line functions relate to the performance of PRA and individual plant examination (IPE) activities and to the optimization of maintenance effectiveness. They facilitate these tasks:

- Managing equipment reliability data and files
- Using plant O&M records to evaluate equipment performance trends for preventive maintenance applications
- Developing and maintaining "living" IPE/PRA studies
- Performing risk/reliability-based evaluations to help resolve routine O&M issues

RAPID's on-line applications are aimed at ensuring the timeliness and accuracy of information important to plant management; they can reduce the work load of plant O&M staff by automating many routine activities. These on-line applications include the following:

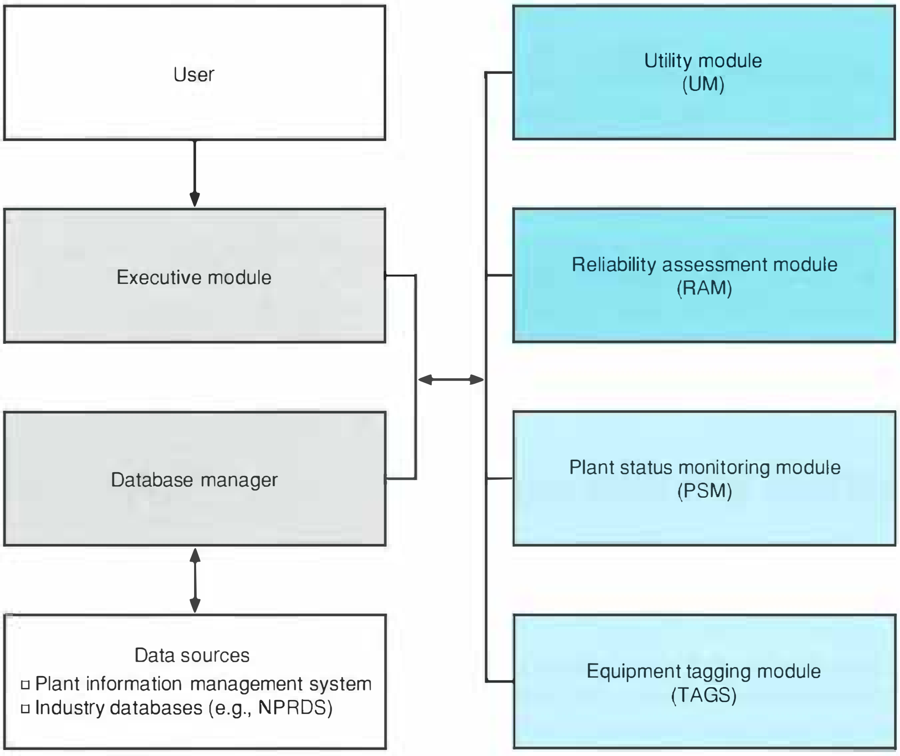
- Monitoring plant equipment status, systems/trains operability, and compliance with technical specifications
- Evaluating power production reliability and system availability
- Assessing the impact of out-of-service equipment on plant system performance reliability
- Ranking equipment in terms of its risk/reliability-based importance to plant safety and productivity, for purposes of preventive maintenance planning
- Automating the equipment tagging procedure, including tag production and report generation

RAPID is available for both IBM mainframe computers and microcomputers. Development and beta testing have just been completed, and the software is in its final prerelease stage. Four regional workshops on RAPID have been held to facilitate technology transfer and the training of utility SRA and PRA staff. Over 20 EPRI member utilities have requested the core RAPID software with various combinations of applications modules.

The RAPID software system consists of many stand-alone modules (Figure 1). Its core comprises an executive module and a relational database manager system. The executive module provides a user-friendly interface and affords users a great deal of flexibility in customizing RAPID to their own software. The database manager administers files and performs other data management functions.

The utility module (UM) and the reliability assessment module (RAM) are used for off-line applications. In combination with the core software, they are the most widely distributed parts of the RAPID system. UM interfaces with automated and/or manual plant information management systems to extract such data as component demand, repair, and failure rates. These data are then used for various reliability-based engineering applications with other applications software, such as CRPS (component reliability parameters system). RAM facilitates IPE/PRA performance and maintenance. It has been designed to allow a variety of IPE/PRA-related computer programs to be linked up with the RAPID databases and to share analysis input and output files. Several EPRI system reliability analysis codes (e.g., CAFTA

Figure 1 RAPID consists of several stand-alone modules: the core software (gray), off-line applications modules (dark color), and on-line applications modules (light color). RAPID supports probabilistic risk assessments and reliability-based O&M activities by facilitating the management of plant-specific and industrywide data and the use of system reliability models.



ABSTRACT *In response to the changing needs of the nuclear power industry, system reliability analysis and probabilistic risk assessment techniques are being applied more broadly: from an initial focus on safety-related design, applications now include operation and maintenance (O&M) issues. RAPID is a software tool for integrating plant information with system reliability engineering to facilitate nuclear operational safety management and enhance plant productivity. RAPID has been implemented by many EPRI member utilities in connection with the current individual plant examination (IPE) effort; it is also being used to help monitor plant status and to support many other O&M activities.*

and NEW-GO) have used this function to automate many routine tasks required in PRA and IPE activities.

Together, the RAPID core modules and the off-line modules UM and RAM provide utility IPE/PRA staff with a powerful software system dedicated to performing system reliability engineering, developing and maintaining IPE/PRA studies, and supporting risk/reliability-based O&M applications. This group of RAPID modules was developed under a cooperative agreement with the Arizona Nuclear Power Project, which also hosted the first RAPID/RAM workshop (in May 1987).

The RAPID on-line applications modules—the plant status monitoring (PSM) module and the equipment tagging (TAGS) module—are state of the art. In conjunction with the core RAPID software, these modules use plant and system logic models as well as information on component status and plant procedures to do the following: determine systems/trains operability; monitor technical specification compliance and track action statements; evaluate plant power production reliability and incremental system unavailability; generate operator shift logs and various user-specified reports; and support complete equipment tagging functions. The engineering information provided by the PSM software serves as an instantaneous, dynamic profile of plant reliability and as a profile of the technical specification compliance of the current plant configuration.

Because of its importance as an aid to decision making related to on-site risk management and routine O&M issues, the PSM software is currently undergoing a preproduction evaluation at the Oyster Creek station of General Public Utilities Nuclear. (The TAGS software is already in production use.) The effort will include daily evaluations of technical specification compliance—evaluations that use both current information on planned component outages provided automatically by the TAGS software and information on unplanned component outages provided by shift technical advisers. At the conclusion of this evaluation period, a determination will be made as to the readiness of the PSM software for production use. Carolina Power & Light's Brunswick plant has conducted a RAPID/PSM pilot study to evaluate the benefits of using this state-of-the-art technology in O&M activities. The on-line portion of the RAPID software has been developed under a cooperative agreement with GPU Nuclear.

Recently, Commonwealth Edison agreed to host and cofund the enhancement of the trending and tracking submodule that is currently a part of the CRPS software. This effort is aimed at extending the statistical analytical package and improving the submodule's user friendliness in evaluations of equipment performance and maintenance effectiveness. It is anticipated that at the completion of this work, the enhanced software will be applied to identify (and prevent) potential recurring equipment maintenance problems and to support reliability-centered maintenance for Commonwealth Edison's systemwide applications. Several EPRI member utilities—including Baltimore Gas & Electric, GPU Nuclear, Niagara Mohawk, the New York Power Authority, and Rochester Gas & Electric—have expressed interest in participating in this effort.

The industry has identified the need to improve the quality of reliability data—specifically, the quality of the industrywide generic database. At present, the CRPS software's generic database is the most complete and qualified of its kind. For use in risk/reliability-based decision-making applications, however, the database must be improved still further. Since all nuclear utilities are required to perform IPEs, plant-specific IPE data will become available. An industrywide ad hoc group, the Utility Reliability Data Swap Group, has been organized with the objective of enhancing this generic database. With EPRI as coordinator, the group will compile IPE/PRA data and organize data exchange between participating utility members. RAPID/UM and CRPS will become the standard software for the group's use.

Plans for RAPID include the development of new modules to support maintenance planning, outage management programs, and risk-based technical specification activities. At present, the focus is on developing technical alliances in IPE/PRA applications to assist EPRI member utilities in the resolution of O&M issues.

Overhead Transmission

Upgrading Lines: Enhanced Analysis Capabilities

by Vito Longo and Paul Lyons, Electrical Systems Division

In many areas of the country load growth is resulting in increased power flows over existing overhead transmission lines. For example, new industrial development or population growth patterns can lead to higher-than-anticipated power flows. Likewise, changing generation patterns can affect power flows. In addition, planners must look to the future to ensure that adequate transmission capacity will be available.

To provide adequate power delivery capability, some utilities are uprating or upgrading their existing overhead transmission lines. Uprating refers to raising the upper limit power transfer capability of a line. Upgrading refers to physical changes to a line that result in uprating or some other performance improvement. Most EPRI work in this area focuses on physical changes to lines—upgrading—to enhance performance. Compared with building a new line, upgrading can be implemented more quickly and at lower cost. Moreover in some cases, obtaining permits may be easier for upgrades than for new lines.

Upgrading transmission lines can involve a variety of changes. For example, to improve power handling capability, the voltage can be increased, or the current-carrying capacity can be increased by using larger or annealed conductors. In each case, these changes have other implications. Increasing the current flow through a line increases the sag and may violate clearance requirements. Increasing the conductor size increases the mechanical loading on transmission towers, possibly necessitating the upgrading of tower structures or foundations. Increasing the voltage may bring into play corona-related radio noise or audible noise issues. Either approach—increasing the current or the voltage—may change the electric and magnetic fields near the line.

Tools for upgrading

The modification of a transmission line has various structural, environmental, and other design implications. In the past, complex transmission modification projects required the use of different software tools (often running on different machines), and users were faced with many different and sometimes difficult regimens for inputting data and giving commands. Obtaining the hardware resources and computer expertise to handle such a variety of tools in-house can be difficult. As a result, outside consultants were often employed to handle various tasks within projects that required the use of software covering multiple disciplines.

The development of EPRI's TLWorkstation™ has made it possible to perform all aspects of a line upgrade analysis with one integrated software package. For example, if an increase in voltage is being considered, engineers can use the new RNOISE TLWorkstation task module to determine whether the proposed design changes meet required radio noise criteria. Other task modules can be used to determine whether electric and magnetic field, audible noise, structural strength, and other criteria are met. The result is a more efficient process that takes into account, and helps users optimize, all aspects of the redesign. The multidisciplinary TLWorkstation makes it possible to consider a wide variety of upgrading approaches because it allows engineers to focus on design problems rather than computer interface problems.

One key advantage of the integrated nature of TLWorkstation is its common database. The data input to a task module such as RNOISE can be transferred to other modules by using the project input module (PIM), new in Version 2.0 of TLWorkstation. The parameters common to more than one data set can be stored in PIM and then be transferred to other task modules for subsequent analysis. This approach obviates the need to re-input the common data, thus reducing the chances of input errors and increasing compatibility among the various analyses.

Evaluating radio noise

The problem of electromagnetic interference from corona on high-voltage power lines has been studied for more than 50 years. For example, the radio noise a motorist hears in the AM broadcast band when driving under a transmission line has been extensively studied. However, traditional methods of estimating the level of radio noise from sources like power lines often have not been able to reliably predict the interference levels beyond 50 feet from the conductors. Regarding interference with television receivers in the very high frequency (VHF) range, only limited analytical methods have been available. Moreover, there have been few tools for predicting electromagnetic interference outside the AM and television broadcast bands.

To help utilities consider electromagnetic interference effects when designing transmission lines, EPRI has developed RNOISE. New for Version 2.0 of TLWorkstation, this task module uses an algorithm that is derived from first principles. Hence RNOISE can accurately predict electromagnetic interference levels for a variety of transmission line designs and for any frequency—AM, FM, television, and so on. Because electromagnetic effects usually become a major concern at voltages of 230 kV and above, this new task module is particularly applicable to projects that upgrade voltage from 115 or 138 kV to 230 kV. In some cases, electromagnetic interference may also be important on lower-voltage lines that utilize compact construction.

Users begin by inputting basic tower configuration data. On the basis of these data, RNOISE calculates the lateral profile of the radio noise. If the proposed redesign does not meet the stipulated radio noise criteria, RNOISE enables the user to easily modify and reevaluate the design.

Confirmed by data from operating lines, RNOISE provides reliable predictions over a wide spectrum of distances from the outer phase. Although the module assumes worst-case noise (i.e., average, stable foul weather conditions), other conditions can also be considered. Intermediate calculations, such as calculations of excitation functions and propagation constants, provide additional analytical detail (see EPRI EL-6420, Vol. 10).

ABSTRACT *Upgrading an existing overhead transmission line to increase its power transfer capability or to realize other performance improvements requires analysis of many factors. The modified line must meet radio and audible noise criteria, have acceptable lightning flashover performance, meet electric and magnetic field criteria, and be structurally sound. New software task modules recently integrated into EPRI's TLWorkstation, together with full-scale testing at EPRI's Transmission Line Mechanical Research Center and High Voltage Transmission Research Center, provide the tools utility engineers need to effectively conduct analyses for upgrading lines.*

Electric and magnetic fields

A key area of analysis in the evaluation of options for line upgrading is the change in electric and magnetic fields (EMF) near the line. An increase in line voltage leads to higher corona-caused noise levels, higher electric fields, and—possibly—lower magnetic fields. To help in the analysis of electric and magnetic fields, researchers at EPRI's High Voltage Transmission Research Center (HVTRC) have developed the TLWorkstation task module ENVIRO.

ENVIRO predicts EMF, maximum conductor voltage gradients, and audible noise levels for overhead transmission lines of many different configurations. By using this module, the EMF impact of proposed changes in designs can be estimated. If necessary, the electrical configuration of the line can be modified to meet EMF criteria (see EL-6420, Vol. 9).

Lightning flashover performance

Transmission line flashovers due to lightning strikes constitute another potential problem that must be addressed when redesigning a line for increased power transfer capacity. These flashovers can cause customer outages, damage utility equipment, and impose heavier duty on breakers, potentially shortening their life. On double-circuit structures, these problems are exacerbated; when one circuit flashes over, the resulting voltage rise on the structure can lead to flashover of the second circuit.

Designers can use another TLWorkstation module, MULTIFlash, to evaluate the lightning flashover performance of a proposed line.

Users choose one of 32 standard-tower equivalent circuits, or develop their own, and input predicted lightning incidence and transmission line length. MULTIFlash then predicts both the number of shielding failures (when a lightning stroke terminates on a phase conductor) and the number of backflashes (when a lightning stroke terminates on a tower top or shield wire but still causes a flashover). If the predicted number of shielding failures and backflashes is unacceptable, line insulation or grounding alternatives can be evaluated to determine necessary configuration changes.

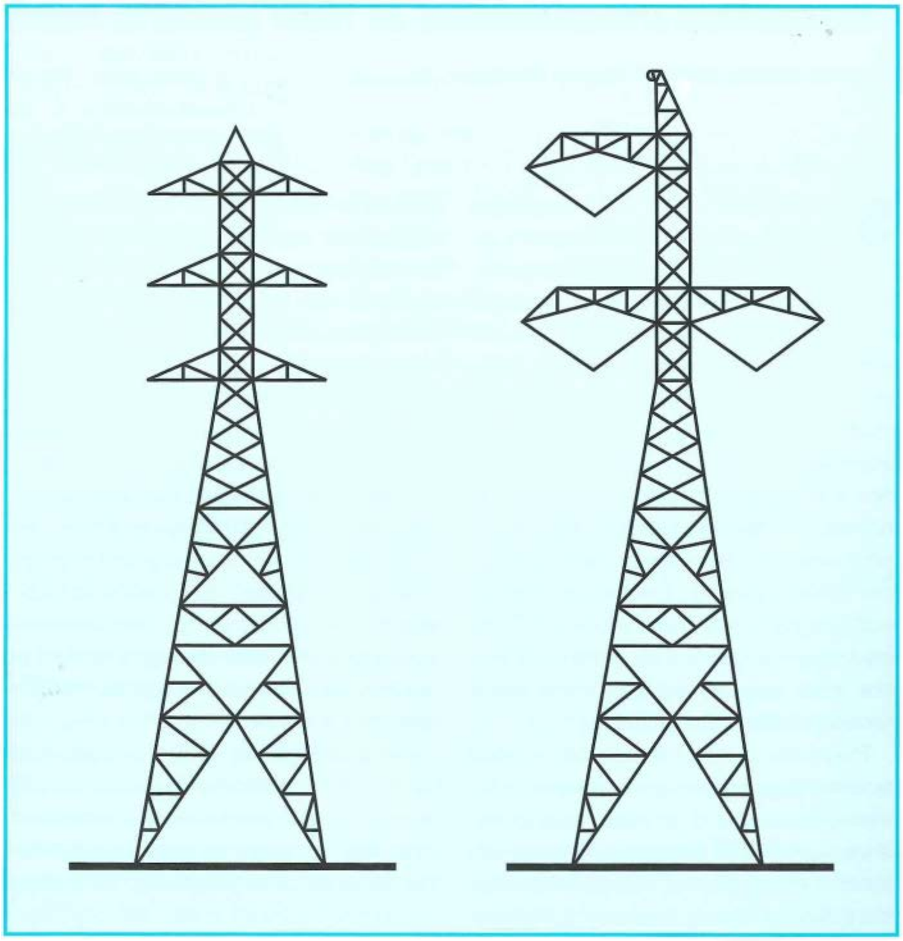
Structural assessment

When upgrading a transmission line, designers must evaluate the existing structures' ability to accommodate increased wire size, increased tensions, increased number of wires, and the like. They need a way to evaluate the capacity of the structures according to existing guidelines and to analyze possible changes to the structures.

To meet this need, EPRI undertook a software development effort that built on user experience with existing structural computer modeling capabilities as well as on results from structural testing at the Transmission Line Mechanical Research Center (TLMRC). The result is software with substantially enhanced capabilities—ETADS (EPRI Tower Analysis and Design System). This program supports 17 specialized elements, or building blocks, that can be used to model lattice, tubular steel, wood pole, guyed, and freestanding structures. These building blocks allow the engineer to realistically simulate the behavior of structures (Figure 1).

ETADS can help designers determine whether a structure can handle the increased mechanical loading of a modified electrical configuration. For example, increasing current flow through existing conductors may increase sag, making it necessary to raise towers to meet minimum clearance requirements. If the structure is guyed, the reduced guy wire angles resulting from raising the tower may reduce its load-bearing capability. The anchors may therefore have to be relocated. If the number of conductors or the conductor size is increased, then areas of the structure may have to be strengthened (see EL-6420, Vol. 23).

Figure 1 Upgrade of a 230-kV double-circuit tower (left) to a 500-kV single-circuit tower, as modeled by the ETADS software in EPRI's TLWorkstation. ETADS enables designers to efficiently identify and optimize structural reconfigurations necessitated by transmission line upgrading.



At the TLMRC in Haslet, Texas, redesigned towers and lines can be tested at full scale. In fact, testing is completely automated at this facility. Load cells, winch controllers, strain gages, and other transducers collect and transmit the data directly to computers. The ability to load structures very accurately and the ability to record and reduce large quantities of data in real time are features that make the TLMRC unique among the world's tower-testing facilities. Experience at the TLMRC has shown that the capacity of many towers currently in use can be increased with minor local strengthening. The key to unlocking this capability is accurate analysis of structural capacity by means of a realistic simulation of the structure and/or a full-scale test (see EPRI Technical Briefs TB.ESD.36.88, TB.ESD.37.88, and TB.ESD.38.88).

TLWorkstation is structured to help engineers conduct a transmission line upgrade project from start to finish. The task modules share a uniform interface for inputting data and commands; the user is prompted in English rather than with computer symbols. Within each of the modules, the TLWorkstation's interactive operation makes it possible to perform quick "what if" analyses. By using this system, engineers and designers can input a proposed redesign, quickly obtain answers, and then alter specific parameters before calculating new results. This system, combined with the full-scale testing capabilities of EPRI's TLMRC and HVTRC, can help utilities efficiently analyze an existing line for upgrading.

Demand-Side Planning

Competitive Procurement of New Electric Resources

by William LeBlanc, Customer Systems Division

ABSTRACT *Utility use of the competitive procurement process to select both supply- and demand-side resources is growing; as of last August, 49 utility solicitations had resulted in bids for more than 15,000 MW of new capacity. This update describes the spectrum of competitive procurement methods being used, outlines the important parameters in evaluating bids, and summarizes many of the internal requirements necessary to complete a successful auction. EPRI's efforts aim to help utilities share timely information on a rapidly emerging approach to meeting future demand.*

Since their first use in 1984, competitive procurement methods have become an important means of obtaining new electric power resources. Their use was motivated in part by an overabundance of power in some regions from qualifying facilities (QFs) under the Public Utility Regulatory Policies Act (PURPA) and by the difficulty in assigning proper avoided costs for payment to QFs. Bidders now include QFs and, in many cases, independent power producers, utility subsidiaries, and third-party demand-side management (DSM) providers. Competitive procurement programs have been initiated both by regulatory agencies and by utilities, and bidding takes place in states that have formal rules and in those that do not.

Though this approach is commonly referred to as bidding, the term competitive procurement process (CPP) is more appropriate, since it can cover a spectrum of resource acquisition efforts ranging from relatively informal simultaneous negotiations to highly structured sealed-bid auctions using quantitative scoring and selection procedures.

As of August 1, 1990, 37 utilities in 17 states and 2 Canadian provinces had issued 49 requests for proposal (RFPs) representing about 15,000 MW of capacity. Table 1 presents a sample of these programs. In view of the increased competitive procurement activity in recent years, EPRI has undertaken several research projects to compile information about the design and evaluation methods used, the results to date, and the key issues faced by utilities who are implementing or contemplating this approach.

At the conclusion of the first phase of its research, EPRI published *Bidding for Electric Resources: An Industry Review* (CU-6089, May 1989). From this research, it became clear that utility competitive procurement programs exhibited substantial variations in such areas as the detail in the RFPs, the information requirements imposed on bidders, and the scoring approaches used. Interviews with managers from the 15 utilities that had direct bidding experience at that time helped identify key issues for future research, including the development of tools to effectively measure nonprice attributes, the incorporation of uncertainty into the bid evaluation process, the integration of demand-side and supply-side bids, and the determination of how contract negotiation can best augment bidding. EPRI also conducted an industry literature search and sponsored an executive-level workshop to offer utility managers involved in competitive procurement an opportunity to interact and share ideas.

The second phase of EPRI's research is building on the growing utility experience with bidding. It seeks to synthesize the wealth of knowledge being gained in the marketplace. The first report from this phase, *Competitive Procurement of Electric Utility Resources* (CU-6898, July 1990), is designed to serve as an industry reference document and covers the complete CPP life cycle. It provides an overview of the bidding and resource-planning process, examining the basic tasks and issues associated with solicitation design, price evaluation, determination and evaluation of nonprice factors, issuance of RFPs, evaluation logistics, awards and contract negotiation, and postcontract follow-up. It emphasizes supply-side procurement.

A companion report, to be published this year, focuses on the unique issues of demand-side bidding. Both the supply-side and demand-side documents are based largely on input from the utilities that have used the competitive procurement process.

Key differences in approach

The competitive procurement programs to date have shown considerable diversity in design characteristics. One major area of difference involves the kinds of resources considered eligible and—if both supply-side and demand-side resources are included—the methods used to integrate supply and demand bids. Other differences involve project scoring and selection methods, the information and level of detail required of bidders, and security requirements.

One useful way to categorize RFPs is by the scoring approach. A key characteristic distinguishing bidding systems is whether or not they use self-scoring evaluation approaches—that is, approaches that allow bidders to calculate a numerical score for their proposals on the basis of information provided in the RFP. Related characteristics are the number and nature of the scoring stages. At one end of the spectrum are RFPs with one-stage, self-scoring processes. At the other end are extremely flexible RFPs, which are sometimes termed competitive negotiations. These generally require less-detailed project and bidder information in the bid, since final decisions will be based on additional communication between the bidder and the purchasing utility.

Another characteristic that distinguishes CPPs from one another involves what can be called project security. There are two major project security considerations: the ability of a developer to get the project built and on-line in a timely manner, and the viability of a project over its contract term. Project development and attrition risks have been addressed in a variety of ways, including the use of threshold requirements, security deposits, and milestones; another approach is to favor (through elevated scores) projects that meet certain development criteria.

Threshold requirements can involve siting, permitting, regulatory approval, financing, and letters of intent; failure to meet the conditions stipulated will preclude a developer's bid from further consideration. Threshold requirements are used to minimize the chance of a project's failing between the time of bid selection and startup.

Security deposits are used to address both developmental risks and risks associated with long-term project viability. Typically, developers are required to post a deposit calculated on a per-kilowatt basis. While security deposits generally are used as a threshold or minimum requirement, recent solicitations have given bidders the option of providing larger deposits in return for higher scores in the project selection process.

Table 1
SELECTED COMPETITIVE PROCUREMENT PROGRAMS

Utility	RFP Date	Capacity Bid (MW)	DSM Type*
Sacramento Municipal Utility District	September 1987	400	
Seminole Electric Cooperative (Florida)	February 1988	440	·
Virginia Power	March 1988	1750	—
Central Maine Power	May 1989	700	Parallel
Florida Power & Light	July 1989	800	—
Virginia Power	August 1989	1100	–
Niagara Mohawk	November 1989	350	Parallel
Public Service Indiana	December 1989	1300	Parallel
Oglethorpe Power (Georgia)	May 1990	700	Integrated
Los Angeles Department of Water & Power	June 1990	600	Parallel

**Parallel* refers to programs that solicited both supply-side and demand-side resources to fill a single resource block objective but used different criteria to evaluate the two resource types; *integrated* refers to programs that used the same evaluation criteria for supply-side and demand-side resources.

Depending on the technology, fuel costs can be an extremely significant component of the cost of producing power from a particular project and can have a significant bearing on long-term project viability. Virtually all solicitations have tied the fuel price component of contract payments to utility fuel prices or some external fuel price index. Also, some RFPs have tried to address risks related to future fuel availability and price through the project selection process—namely, by favoring local fuels or fuels with less price volatility.

Administration and internal logistics

The administration of competitive procurement programs is time-consuming. The efforts exerted by utilities can be divided into two major categories: project selection and contract negotiation. Although activities in each category are subject to a learning curve, even the most experienced utilities have found that the process continues to require substantial effort. Some utilities develop RFPs and select projects entirely with in-house staff, while others use consultants to develop the RFP, assist with project selection, or assess the results.

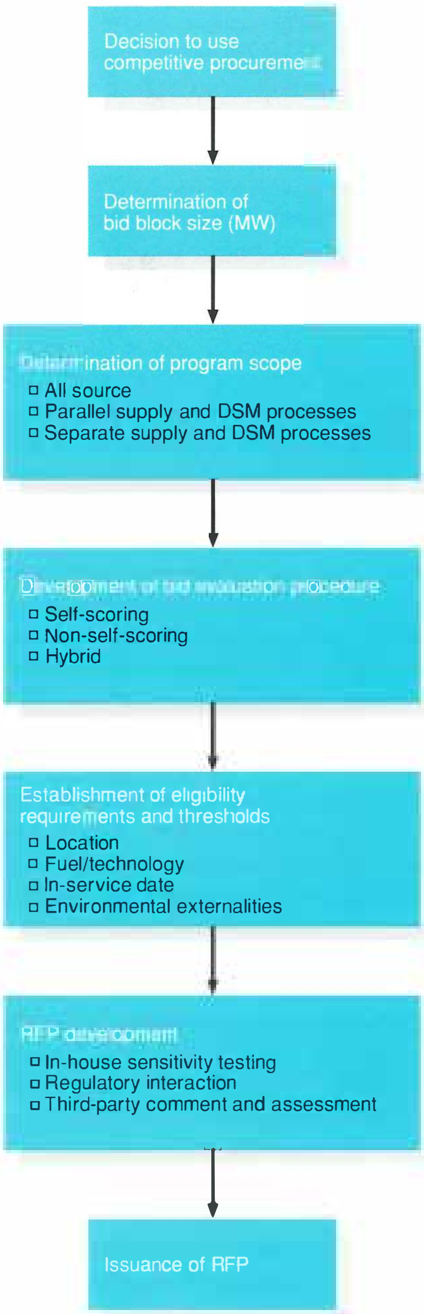
The learning effects are generally greatest in RFP design and issuance and in proposal evaluation. One reason for the time savings is that senior management is usually much more involved in the review and approval of the first competitive purchase than in later ones. Another is that regulatory approval, if required, usually takes longest for the first rulemaking.

Competitive procurement is still in its formative stages, and the technical and business environment continues to change at a rapid pace. As a result, utilities must maintain their efforts to stay abreast of market developments and to assess their own competitive procurement experiences in the context of efforts elsewhere in North America.

Demand-side resources

Competitive procurement can be applied to a range of demand-side options, including lighting retrofits, high-efficiency motors and appliances, and the revamping of industrial processes to save demand and energy. Although the EPRI demand-side reference document is still in preparation, a number of im-

Figure 1 A utility must consider many issues and options in designing a competitive procurement program to select new supply- and/or demand-side resources. Each step of the process is influenced by the utility's goals and philosophy and by the regulatory and market environment. The utility's resource-planning needs (i.e., resource/fuel mix, load/resource balance, and projected load growth) influence decisions on both the bid block size and the program scope. The growing industry experience with competitive procurement can be useful in making those and other design decisions.



portant issues and trends have been identified. The various approaches to obtaining DSM resources can be placed on a spectrum of procurement methods.

On one end of the spectrum are programs in which the utility plans, administers, and delivers DSM services to the customer. This approach builds on the utility's relationship with its customers and is seen by some utilities as a significant strategic tool. On the other end of the spectrum is the "pure" bidding approach, where customer and third-party DSM programs compete with generation resources to meet projected needs for new power supplies; that is, DSM is regarded as equivalent to kilowatts and kilowatthours. In the middle of the spectrum are a host of mixed approaches —such as competitive procurement of utility-specified DSM services, or shared savings and performance contracting programs.

The question of how and to what extent to use third parties for DSM is an extremely significant one. One issue concerns the corporate goals underlying the utility's own DSM efforts. In cases where utility demand-side programs are used as an important strategic tool, DSM bidding must be approached in a manner consistent with the strategic goals.

Especially important is the three-way relationship that DSM bidding creates between the utility, its customers, and third-party DSM providers. Views about the implications of this three-way relationship differ significantly among utilities contemplating and carrying out DSM bidding programs. Some, seeing third parties in much the same role as independent power developers, enter into arm's-length contractual relationships. Others view third-party DSM providers as a utility's representatives and strive for a close, flexible working relationship.

There are also differences in how these DSM services are presented to the customer. Some utilities employ franchises to limit the number of third parties providing any one type of service or serving any one geographic area. Such franchising is used to ensure that customers are not presented with a confusing array of DSM options and providers. On the other hand, some utilities view a wider array of customer choices as a better way of meeting their customers' needs.

Utilities and regulators have flagged several key concerns about competitive procurement for demand-side resources. One issue involves what some consider the Achilles' heel of DSM bidding—the practice popularly known as cream-skimming, in which bidders focus only on the least-expensive DSM measures. Since there are certain fixed administrative costs associated with DSM implementation, many observers think that bidding will result in the loss of more-expensive DSM resources that are nonetheless cost-effective when addressed on a comprehensive, programmatic basis.

Another concern is how to measure DSM savings. While this question must be addressed regardless of the way in which demand-side resources are acquired, the introduction of third parties can cause measurement issues to loom large.

Design of an overall process

If competitive methods are used to procure demand-side resources, the question arises as to how these efforts should be coordinated with supply-side competitive procurement efforts. The issue at hand is how to allow cost-effective demand-side resources to play a substantial role in meeting new resource needs, while at the same time accounting for the fundamental differences between demand-side management and electricity generation. Utilities have taken a variety of approaches to this problem, including the use of bidding for supply resources only, the institution of separate solicitation processes for DSM and generation (i.e., separate bid blocks, RFPs, and timeframes), the institution of parallel supply- and demand-side processes for a single bid block, and the use of fully integrated solicitations open to both DSM and generation projects.

The elements discussed above are just a few of the many considerations that come into play in the design of a competitive procurement program suited to the needs and circumstances of an individual utility. Figure 1 illustrates the design process in the context of these considerations.

Competitive procurement methods have become an increasingly important part of the electric power planning and resource acquisition picture. The utilities that have implemented competitive procurement have taken diverse approaches in terms of types of resources sought, project selection methods, security requirements, and contracting practices.

The best procurement program for any one utility depends on many issues, including the utility's goals and philosophy, its mix of existing power resources, and its projections of future load growth. The exact role that competitive procurement will take in the upcoming decade will depend largely on such new developments as changes in the regulatory structure and laws governing utilities, technological advances, new environmental developments and/or mitigation requirements, and the dynamics of worldwide fossil fuel markets.

Rotating Machinery

Generator Retaining Ring Examination

by Jan Stein, Generation and Storage Division

In most modern electric generators, a nonmagnetic retaining ring at each end of the rotor contains the field winding end turns. Many of these rings are made of a cold-expanded alloy with 18% manganese and 5% chromium. Although well suited to this use in terms of strength and fracture toughness, this alloy is highly susceptible to intergranular stress corrosion cracking (IGSCC) in the presence of moisture or other contaminants. When this cracking leads to ring rupture, catastrophic failure of the generator can result. In addition to posing the risk of human injury, such a failure usually necessitates massive internal repair, including stator and rotor winding replacement. Also, the release of hydrogen from inside the generator can cause fires.

The critical crack size (the size at which failure occurs) is usually relatively large for these rings. However, stress corrosion crack growth rates can be rapid if the unit is exposed to moisture from leaks or condensation; under these conditions, a crack may propagate to failure in as short a time as 1000 hours. This high rate of crack growth complicates the use of fracture mechanics techniques to determine inspection intervals. And removing a ring can itself cause damage. Consequently, in-service examination methods are needed to detect cracks when they are small enough that they will not grow to a critical size before the next inspection. In combination with effective moisture prevention measures, in-service examination can provide adequate assurance of continued safe operation.

Although nondestructive evaluation (NDE) techniques have been used to detect cracks in retaining rings, test practices vary considerably around the world. In some cases, cracks have escaped detection; in others, indications have been incorrectly interpreted. The alternative to ring testing, installing new rings of stress-corrosion-resistant material, can be very expensive—$250,000 to $500,000 or more per generator.

EPRI has two main goals in this area: to help utilities identify the proper method or combination of methods to use in examining rings for IGSCC, and to serve as a source of comprehensive, objective information for the utility industry.

To achieve the first goal, EPRI's Nondestructive Evaluation Center in Charlotte, North Carolina, began work in 1986 to identify appropriate NDE techniques for examining generator retaining rings. The primary objective of this project (RP2719) is to identify means of detecting and sizing IGSCC without removing the ring from the rotor. Because many of the most probable IGSCC initiation sites are along the inner surfaces of rings, ultrasonic examination

ABSTRACT *To help utilities identify the proper method or combination of methods to use in examining generator retaining rings for stress corrosion cracking, EPRI's Nondestructive Evaluation Center is demonstrating commercially available ultrasonic and eddy-current testing techniques at several utilities. EPRI is also developing a PC-based retaining ring workstation that integrates commercially available testing modules into a user-friendly system with high-speed data acquisition and high-resolution imaging capabilities. Another tool under development, a retaining ring life assessment code, will aid in effective maintenance planning.*

techniques have emerged as the only practical means of attaining this objective.

Sometimes, however, retaining rings are removed for some other purpose, such as to make winding repairs. Ultrasonic techniques have been found to be ineffective in this situation, because when the tensile assembly stresses are removed, there is a crack closure effect. EPRI has evaluated the use of eddy-current techniques to identify cracks in rings removed from rotors. Because these techniques can detect even minor damage, they can effectively be used to confirm damage initially identified by ultrasonic techniques.

In connection with its role as an objective information source, EPRI sponsored a generator retaining ring workshop in 1987. Held in Charlotte, the workshop consolidated industry experience and facilitated the exchange of information on retaining ring inspection, repair, and replacement. The 200 participants represented a broad spectrum of utilities, equipment manufacturers, forging suppliers, service organizations, universities, insurance carriers, and consultants from around the world. The workshop presentations have been published in EPRI EL-5825.

In-service examination

As a result of two years of EPRI-sponsored experimentation, researchers have identified in-service ultrasonic test techniques that complement each other and that together can be used to provide a comprehensive ring evaluation. A screening test should first be performed by means of conventional pulse-echo techniques, including 45° S-wave or inside-surface creeping-wave techniques. A high-quality imaging system should be used for this detection scan, and areas where questionable indications are noted should be evaluated in more detail by using advanced crack detection and sizing techniques, such as mode-converted L-wave, time-of-flight diffraction (TOFD), and feature analysis techniques.

A combination of these methods was first used in May 1989 in EPRI-sponsored field trials at the Tennessee Valley Authority's Gallatin power plant. A conventional ultrasonic inspection was first performed to identify suspect areas. For this purpose, an IntraSpect/98 system (Amdata Systems) was used with an automated scanner to demonstrate creeping-wave techniques over the entire shrink-fit areas of both rings. By means of computer-generated images, various indications were displayed. Periodically recurring patterns associated with similar geometry were quickly and easily identified and eliminated from further consideration.

Signals that did not fit the pattern were isolated for further inspection. The Zipscan system—an ultrasonic system built by Sonomatic that can make TOFD-type measurements—was used for this more detailed examination of selected regions. In this method, two transducers, a transmitter, and a receiver are used in a pitch-catch mode to detect waves that are diffracted by sharp crack tips. To identify a crack, differences in flight time between the tip signal and the reflection from the ring's inner surface are determined. The resulting interference pattern confirmed some damage.

Retaining ring workstation

Early in EPRI's involvement, NDE Center personnel found that there are several commercially available test systems capable of performing certain aspects of a retaining ring evaluation. In each case, however, some limitation precludes the performance of certain other key parts of the evaluation. For example, some systems do not provide the resolution and speed of presentation needed for some analyses, while others have superior display capabilities but limited data acquisition hardware. Another complication is that the systems use different computer hardware and software.

To solve this problem, the NDE Center is developing a PC-based retaining ring workstation. This system will integrate commercially available modules for automatic ultrasonic and eddy-current testing of retaining rings into one workstation. Because it is PC-based, the system can easily be used at utility power plants, with no need for new computing hardware. The workstation will also accommodate automated data acquisition and high-speed signal processing, high-resolution imaging, and report generation.

Although the workstation is not yet completed, some of its capabilities have been

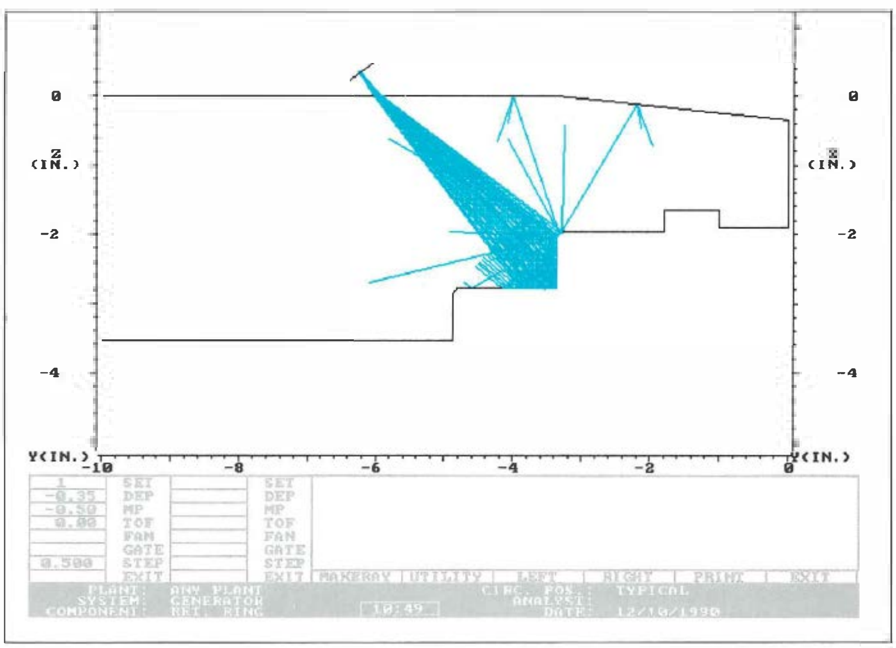


Figure 1 The RAYTRACE software facilitates the nondestructive examination of plant components with ultrasonic testing by quickly and accurately plotting ultrasonic beam paths. This capability helps investigators design examination procedures and analyze and document results. In this example, RAYTRACE is demonstrated on a retaining ring nose.

demonstrated in in-plant ultrasonic testing, first at the Lower Colorado River Authority's Sim Gideon Unit 3 and later at Consolidated Edison's Astoria station. When completed, this system will also be applicable to ultrasonic and eddy-current testing of piping and other key power plant components.

RAYTRACE computer code

A capability that has recently been added to the retaining ring workstation is the RAYTRACE software tool. When performing ultrasonic examinations, the operator relies on accurate in-scale plotting of ultrasonic beams for designing examination procedures and for analyzing and documenting results. The ultrasonic beam undergoes attenuation, reflection, and mode conversion during propagation through the material. Manual calculation and plotting of these beams can be time-consuming, especially for complex geometries.

The NDE Center has developed the RAYTRACE software to perform the beam calculations and to plot the resulting beam paths quickly and accurately (Figure 1). RAYTRACE runs on PC-based systems that support a range of graphic and plotting devices. It is a user-friendly, mouse-driven system that provides two-dimensional color graphic simulations of ultrasonic wave propagation.

Eddy-current testing

In addition to ultrasonic testing, EPRI has been involved in eddy-current testing of retaining rings (Figure 2). The eddy-current NDE method has long been recognized for its ability to detect surface and near-surface discontinuities in electrically conductive materials. In fact, it has been used and recommended for retaining ring inspection by some vendors.

Application of eddy-current techniques requires ring removal, however, which is not typically recommended for initial ring inspection. In cases where the rings must be removed for some other reason, such as to perform winding repairs or to confirm an indication of cracking obtained from initial ultrasonic testing, eddy-current techniques offer superior sensitivity and reliability. Unlike liquid penetrant and ultrasonic techniques, eddy-current techniques can detect cracks even though the cracks close up when the ring is removed from the rotor.

Figure 2 In cases where retaining rings are removed from rotors—to facilitate generator repair or to confirm an indication of ring cracking—eddy-current techniques can be used to obtain high-quality ring images. EPRI-sponsored researchers have tested this eddy-current system on retired rings, with good results.

In a recent EPRI-sponsored eddy-current demonstration, Florida Power and Light (FP&L) removed retaining rings from a generator at its Port Everglades station. Because the rings were rusty, the utility suspected that replacement might be necessary. However, eddy-current testing at a repair facility in Charlotte revealed only minor cracks, which could be removed by making a thin machine cut of the surface. The rings were machined, reinspected, and reinstalled without extending the planned outage. Besides avoiding the cost of ring replacement, FP&L avoided the delay of unit restart that procuring new rings would probably have entailed. Retaining ring eddy-current testing has also been successfully conducted at Carolina Power & Light, Pennsylvania Power, and the Tennessee Valley Authority.

Ongoing work

Ongoing EPRI efforts include the completion of the retaining ring workstation, the development of a retaining ring life assessment code, and the establishment of a self-supporting users group.

The life assessment code, which will ultimately be incorporated into the retaining ring workstation, will enable utilities to estimate the probability of failure for a given ring under prevailing or postulated conditions. By conducting a fracture mechanics treatment of fatigue, stress corrosion, and hydrogen-assisted crack growth, this tool will assess the risk of ring failure. Utilities can then use the results in deciding what action to take—more frequent inspection, repair, or replacement. With this approach, utilities will be able to plan an effective maintenance strategy for nonmagnetic retaining rings.

A utility retaining ring users group is being formed to act as the primary vehicle of information transfer for the industry. The group's objectives include making reliable and cost-effective retaining ring assessment technology available to utilities, investigating the feasibility of maintaining a pool of retaining ring forgings, and ensuring continuing reliable service for existing retaining rings.

New Contracts

Project	Funding/ Duration	Contractor/EPRI Project Manager
Customer Systems		
Development of Manufacturing End-Use Model (RP2217-4)	$64,800 7 months	Regional Economic Research/*P. Hummel*
Guide to Assessing the Impacts of DSM Programs (RP2548-11)	$82,500 8 months	RCG/Hagler, Bailly/ *P. Hanser*
Advanced Metering and Customer Interface Research: Issues and Priorities (RP2568-17)	$56,700 7 months	Levy Associates/ *L. Carmichael*
Zero-Ozone-Depletion-Potential Alternatives for Commercial Space Conditioning and Refrigeration (RP2891-14)	$93,000 17 months	Oak Ridge National Laboratory/*M. Blatt*
Water Heater Accelerated-Liming Test Facility (RP2958-12)	$208,400 24 months	Battelle, Columbus Laboratories/*C. Hiller*
Development of User-Friendly Water-Heating Model (RP2958-16)	$82,500 12 months	Arthur D. Little/*C. Hiller*
Development of Prototype Electric Utility Gateway (RP3163-2)	$357,800 9 months	Honeywell/*L. Carmichael*
Electrical Systems		
Protective Relay Workstation (RP3192-1)	$171,000 25 months	Texas A&M Research Foundation/*L. Mankoff*
Investigation of Geomagnetically Induced Currents (RP3211-2)	$752,600 22 months	Minnesota Power & Light Co./*J. Porter*
High-Frequency Link Converters as FACTS Elements (RP4000-19)	$100,600 17 months	University of Florida/ *D. Maratukulam*
Detection of Leaks in Power Transmission Cables (RP7910-8)	$64,600 9 months	Vista Research/ *J. Shimshock*
Robotic Mouse for Instrumenting HPLF Pipe-Type Cable: Design and Fabrication (RP7910-9)	$71,700 4 months	Foster-Miller/ *T. Rodenbaugh*
Distributed Fiber-Optic Leak Detection (RP7910-11)	$300,000 13 months	Battelle, Columbus Laboratories/ *T. Rodenbaugh*
Improvement of Current Capacity in YBaCuO Superconducting Materials Above 200 K (RP7911-17)	$50,000 13 months	Wayne State University/ *M. Rabinowitz*
Environment		
Regional Air Quality Studies: Characterization of Atmospheric Acidity (RP1630-59)	$416,000 24 months	Harvard University/ *M. Allan*
Experimental Study of Formation Mechanisms and Properties of Atmospheric Particles (RP2023-11)	$489,200 22 months	University of Minnesota/ *P. Saxena*
Investigations of Ambient Hydroperoxides (RP2023-12)	$158,000 23 months	University of Rhode Island/*D. Hansen*
Framework for Evaluating Policy Options for Dealing With Global Climate Change (RP2141-19)	$100,000 21 months	Harvard University/ *L. Levin*
Ocean Phytoplankton Trends and Biological Carbon Fixation (RP2333-10)	$166,200 22 months	Brookhaven National Laboratory/*C. Hakkarinen*
Exploratory Research		
Mechanical Deformation Effects on Magnetic Properties (RP2426-29)	$221,800 28 months	Southwest Research Institute/*S. Gehl*
Smart Temperature Sensors (RP8004-4)	$120,300 24 months	University of Tennessee/ *J. Weiss*
Fast Chemical Sensor Using Frequency-Modulated Spectroscopy (RP8004-8)	$1,145,300 34 months	SRI International/ *D. Hansen*
Development of Design Fundamentals for Low-NO_x Multiannular Swirl Burners (RP8005-9)	$150,000 27 months	Massachusetts Institute of Technology/*A. Kokkinos*
Generation and Storage		
Measurement and Computer Modeling of Amorphous Silicon Properties Related to Improved Stability (RP1193-14)	$259,400 12 months	Pennsylvania State University/*T. Peterson*
Development of a Coal Quality Expert System (RP1400-25)	$5,931,100 41 months	CQ Inc./*R. Row*
Implementation of Optimal Regulator at Bertron Unit 1 (RP1403-52)	$60,000 6 months	Houston Lighting & Power Co./*M. Divakaruni*
Containment of Combustion Wastes (RP1457-7)	$492,200 37 months	ICF Incorporated/ *M. McLearn*
In Situ Formation of Impermeable Barriers by Radio-Frequency Heating (RP1457-9)	$171,200 12 months	IIT Research Institute/ *M. McLearn*
Evaluation of a 2-MW Molten Carbonate Fuel Cell Power Plant Operating on Landfill Gas (RP1677-19)	$50,900 4 months	Haldor Topsoe/*D. Rastler*
Effect of Overhaul on Equipment Availability (RP2462-2)	$99,400 12 months	ARINC Research Corp./ *J. Weiss*
Development of Reheat Combustor–Power Turbine Packages (RP2620-9)	$195,300 47 months	Energy Storage & Power Consultants/*A. Cohn*
Control System Tuning and Maintenance Guidelines (RP2710-17)	$337,200 26 months	Gibbs & Hill/*D. O'Connor*
Control System Man-Machine Interface Guidelines (RP2710-20)	$176,800 24 months	General Physics Corp./ *M. Divakaruni*
Survey to Establish a Program to Resolve Utility Concerns Regarding IGCC (RP2773-13)	$126,400 13 months	Sargent & Lundy Engineers/*N. Hertz*
Nuclear Power		
Electrochemical Ion Exchange of LOMI (RP1329-6)	$128,500 11 months	Bradtec/*C. Wood*
Fracture Toughness Study on Type 304 Core Grid Material (RP2455-23)	$84,000 7 months	VTT Technical Research Centre of Finland/ *J. Gilman*
Determining the Effectiveness of Plant Layup and Equipment Preservation Techniques (RP2495-15)	$231,000 17 months	Babcock & Wilcox Co./ *G. Allen*
Radiation Hardening of Smart Transmitter Electronics (RP2614-58)	$80,000 12 months	Sandia National Laboratories/*J. Weiss*
MAAP/MELCOR Comparison Calculations for Point Beach (RP2637-16)	$60,000 7 months	University of Wisconsin at Madison/*E. Fuller*
Ultrasonic Inspection Training Simulator Development (RP3148-1)	$92,000 9 months	Sierra Dataplex/*S. Liu*
Hydrogen Water Chemistry: Fuel Materials (RPC101-14)	$650,800 36 months	General Electric Co./ *R. Yang*
Residual Stress Analysis in Reactor Pressure Vessel Attachments (RPC102-3)	$107,100 11 months	Southwest Research Institute/*M. Behravesh*
Stress Corrosion Cracking of Reactor Pressure Vessel Steels (RPC102-6)	$73,600 5 months	Babcock & Wilcox Co./ *R. Pathania*
Tube Support Plate Tube-Plugging Criteria Limits: Technical Support (RPS404-32)	$59,500 19 months	Westinghouse Electric Corp./*L. Williams*
Kewaunee Steam Generator Tube Examination (RPS407-42)	$104,200 6 months	Westinghouse Electric Corp./*P. Paine*

New Technical Reports

Requests for copies of reports should be directed to Research Reports Center, P.O. Box 50490, Palo Alto, California 94303; (415) 965-4081. There is no charge for reports requested by EPRI member utilities, U.S. universities, or government agencies. Reports will be provided to nonmember U.S. utilities only upon purchase of a license, the price for which will be equal to the price of EPRI membership. Others in the United States, Mexico, and Canada pay the listed price. Overseas price is double the listed price, except as noted. Research Reports Center will send a catalog of reports on request. To order one-page summaries of reports, call the EPRI Hotline, (415) 855-2411.

CUSTOMER SYSTEMS

Data Collection for CLASSIFY™ and PULSE
EM-5906 Final Report (RP2671-1); $100
Contractor: National Analysts
EPRI Project Manager: L. Lewis

Textile Industry: Profile and DSM Options
CU-6789 Final Report (RP2885-1); $100
Contractors: Resource Dynamics Corp.; Battelle, Columbus Division
EPRI Project Manager: P. Meagher

Estimating Efficiency Savings Embedded in Electric Utility Forecasts
CU-6925 Final Report (RP2788); $100
Contractor: Barakat & Chamberlin, Inc.
EPRI Project Manager: T. Yau

Heat Pump Thermal Distribution Systems, Vols. 1 and 2
CU-6962 Final Report (RP2892-2); $100 each volume
Contractor: Tecogen, Inc.
EPRI Project Manager: J. Kesselring

Cogeneration and Independent Power Production: Market Insight and Outlook
CU-6964 Final Report (RP2950-2); $95
Contractor: Resource Dynamics Corp.
EPRI Project Managers: H. Gransell, W. LeBlanc

Least-Cost Planning in the United States: 1990
CU-6966 Final Report (RP2982-2); $25
Contractor: Barakat & Chamberlin, Inc.
EPRI Project Manager: P. Hanser

Proceedings: Ventilation Workshop, Vols. 1 and 2
CU-6972 Proceedings (RP2034-34); $100 each volume
Contractor: Energy International, Inc.
EPRI Project Managers: J. Kesselring, R. Wendland

ELECTRICAL SYSTEMS

Manual on Estimating Soil Properties for Foundation Design
EL-6800 Final Report (RP1493-6); $47.50
Contractor: Cornell University
EPRI Project Manager: V. Longo

Gas-Insulated Substation Spacer Surface Degradation Analysis, Vol. 1
EL-6856 Final Report (RP1360-10); $25
Contractor: Ontario Hydro Research Division
EPRI Project Managers: F. Garcia, V. Tahiliani

Development of Moisture Barriers for Extruded Dielectric Transmission Cables
EL-6857 Final Report (RP7897-3); $200
Contractor: Springborn Laboratories, Inc.
EPRI Project Manager: B. Bernstein

Impurities in Extruded Cables: A Proton-Induced X-Ray Emission Diagnostic Study
EL-6859 Final Report (RP2713-4); $25
Contractor: Institut de Recherche d'Hydro-Québec
EPRI Project Manager: B. Bernstein

Electrokinetic Effects in Power Transformers
EL/ER-6880 Interim Report (RP8000-1); $32.50
Contractor: Rensselaer Polytechnic Institute
EPRI Project Manager: S. Lindgren

Advanced Tree-Trimming Equipment
EL-6901 Final Report (RP2358-1); $25
Contractor: Environmental Consultants, Inc.
EPRI Project Manager: H. Ng

Effects of Voltage Surges on Solid-Dielectric Cable Life
EL-6902 Interim Report (RP2284-1); $32.50
Contractors: Georgia Power Co.; Southern Electric International Research Center
EPRI Project Manager: H. Ng

Multi-Area Power System Reliability and Production Costing
EL-6912 Final Report (RP2473-18); $32.50
Contractor: University of Oklahoma
EPRI Project Manager: R. Adapa

Workshop Proceedings: Static Electrification in Power Transformers
EL-6918 Proceedings (RP1499-98); $47.50
EPRI Project Manager: S. Lindgren

Development of a Composite System Reliability Evaluation Program, Vols. 1–3
EL-6926 Final Report (RP2581-2); $25 each volume
Contractor: Power Systems Research Inc.
EPRI Project Manager: N. Balu

Development of 230-kV High-Pressure, Gas-Filled, Pipe-Type Cable System: Model Test Program Phase
EL-6933 Interim Report (RP7908-1); $32.50
Contractor: Pirelli Cable Corp.
EPRI Project Manager: J. Shimshock

Flexible AC Transmission Systems (FACTS): Scoping Study—Vol. 1, Part 1 (Analytical Studies)
EL-6943 Final Report (RP3022-1); $32.50
Contractor: Power Technologies, Inc.
EPRI Project Manager: D. Maratukulam

The DC Modeling Program (DCMP), Version 2.0, Vols. 1–3
EL-6959 Final Report (RP1964-4); Vol. 1, $25; Vol. 2, $47.50; Vol. 3, $47.50
Contractor: Manitoba HVDC Research Centre
EPRI Project Manager: M. Lauby

EXPLORATORY RESEARCH

Development of a Cyclic Damage Evaluation Method
ER/NP-6928 Final Report (RP2414-10, RP2426-19); $25
Contractor: Ishikawajima-Harima Heavy Industries Co., Ltd.
EPRI Project Manager: M. Lapides

GENERATION AND STORAGE

FGD Chemistry and Analytical Methods Handbook, Vol. 1
GS-3612 Final Report (RP1031-13); $500
Contractor: Radian Corp.
EPRI Project Manager: R. Moser

Release and Attenuation of PCB Congeners: Measurement of Desorption Kinetics and Equilibrium Sorption Partition Coefficients
GS-6875 Final Report (RP1263-22); $32.50
Contractor: Battelle, Pacific Northwest Laboratories
EPRI Project Manager: M. McLearn

Modular Wellhead Binary Power System: Preliminary Design Results
GS-6890 Final Report (RP2195-6); $55
Contractor: Pacific Gas and Electric Co.
EPRI Project Manager: J. Berning

Evaluation of a Dow-Based Gasification–Combined-Cycle Plant Using Bituminous Coal
GS-6904 Final Report (RP2699-11); $40
Contractor: Fluor Daniel, Inc.
EPRI Project Manager: M. Gluckman

Use of Circulating-Fluidized-Bed Combustors in Compressed-Air Energy Storage Systems
GS-6905 Final Report (RP2999-2); $32.50
Contractor: Energy Storage and Power Consultants, Inc.
EPRI Project Manager: B. Louks

Evaluating Hydro Relicensing Alternatives: Impacts on Power and Nonpower Values of Water Resources
GS-6922 Final Report (RP2694-7); $100 (overseas price the same)
Contractor: Decision Focus, Inc.
EPRI Project Managers: J. Birk, C Sullivan

Investigation of Flue Gas Desulfurization Chemical Process Problems
GS-6930 Interim Report (RP2248-1); $1000
Contractor: Radian Corp.
EPRI Project Manager: R. Moser

Feedwater Heaters Maintenance and Repair Technology: Reducing Outage Cost
GS-6935 Final Report (RP2504-5); $500
Contractors: Sonalysts, Inc.; Powerfect, Inc.
EPRI Project Manager: J. Tsou

Control Upgrade Study for Huntley Unit 65, Vols. 1–3
GS-6961 Final Report (RP2710-11); Vol. 1, $25; Vol. 2, $55; Vol. 3, $32.50
Contractors: Niagara Mohawk Power Corp.; Science Applications International Corp.; Stone & Webster Engineering Corp.
EPRI Project Manager: M. Divakaruni

Proceedings: 1989 EPRI Heat-Rate Improvement Conference
GS-6985 Proceedings (RP1711-10); $85
Contractor: Plant Performance
EPRI Project Manager: R. Leyse

NUCLEAR POWER

Guide for the Application and Use of Valves in Power Plant Systems
NP-6516 Final Report (RP2233-5); $25,000 (overseas price the same)
Contractor: Stone & Webster Engineering Corp.
EPRI Project Manager: J. Lang

Nondestructive Evaluation Research Progress in 1989: Proceedings From the Tenth Annual EPRI NDE Information Meeting
NP-6609 Proceedings; $55
EPRI Project Managers: G. Dau, S. Liu

Corrosion Evaluation of Thermally Treated Alloy 600 Tubing in Primary and Faulted Secondary Water Environments
NP-6721-M Final Report (RP1708-2); $25
NP-6721-SD Final Report; $10,000
Contractor: Westinghouse Electric Corp.
EPRI Project Managers: C. Shoemaker, P. Paine

A Simplified Inelastic Seismic Analysis Method for Piping Systems
NP-6809 Final Report (RP2350-2); $62.50
Contractor: Rockwell International
EPRI Project Manager: H. Tang

Nondestructive Evaluation of Component Interiors
NP-6811 Final Report (RP2057-10); $32.50
Contractor: Southwest Research Institute
EPRI Project Manager: M. Avioli

Nondestructive Evaluation of Component Interiors: Technology Assessment
NP-6832 Final Report (RP2057-11); $47.50
Contractor: Sea Test Services
EPRI Project Manager: M. Avioli

Implementation Guidelines for Chemistry Expert Systems at Power Plants
NP-6843 Final Report (RP2582-15); $25
Contractor: NWT Corp.
EPRI Project Manager: B. Sun

Irradiation-Induced Changes in Zircaloy Intermetallics
NP-6872 Final Report (RP1250-14); $9000
Contractor: University of California, Berkeley
EPRI Project Managers: A. Machiels, P Rudling

Video Camera Use at Nuclear Power Plants: Tools for Increasing Productivity and Reducing Radiation Exposure
NP-6882 Final Report (RP2705-13); $500 (overseas price the same)
Contractor: ENCORE Technical Resources, Inc.
EPRI Project Manager: J. O'Brien

Fuel Consolidation Demonstration Program: Cold and Hot Demonstrations
NP-6893 Interim Report (RP2240-2); $32.50
Contractor: Northeast Utilities Service Co.
EPRI Project Manager: R. Lambert

Volume Reduction Technologies for Ion-Exchange Resins Arising From Full-System Decontamination of Nuclear Power Reactors
NP-6917-M Final Report (RP2296-21); $25
NP-6917-SD Final Report; $5000
Contractor: PN Services, Inc.
EPRI Project Managers: C. Spalaris, C. Wood

The Cleanup of Three Mile Island Unit 2: A Technical History, 1979 to 1990
NP-6931 Final Report (RP2558-8); $47.50
Contractor: Grove Engineering, Inc.
EPRI Project Manager: R. Lambert

High-Temperature Optical-Fiber pH Sensors
NP-6932 Final Report (RP2614-5); $25
Contractor: Lawrence Livermore National Laboratory
EPRI Project Manager: T. Passell

Solidification in Cement of Ion-Exchange Resins From LOMI Decontamination
NP-6934 Final Report (RP1329-4); $25
Contractor: John V. Bishop
EPRI Project Managers: C. Wood, C. Spalaris

Soil-to-Plant Transfer of Carbon-14 for Environmental Assessment of Radioactive Waste Repositories
NP-6946 Final Report (RP2691-9); $25
Contractor: Atomic Energy of Canada Limited Research Co.
EPRI Project Manager: C. Hornibrook

PLANNING

Natural Gas for Electric Power Generation: Strategic Issues, Risks, and Opportunities
P-6820 Final Report (RP3201-1); $25
Contractors: Strategic Decisions Group; Energy Ventures Analysis, Inc., Jensen Associates, Inc.; Pace Consultants, Inc., Putnam, Hayes, and Bartlett
EPRI Project Manager: H. Mueller

CALENDAR

For additional information on the meetings listed below, please contact the person indicated.

MARCH

13–14
NMAC Maintenance Issues: 1st Annual Conference and Workshop
New Orleans, Louisiana
Contact: Joey Johnson, (415) 855-2056

13–15
Energy Management Systems
Washington, D.C.
Contact: Mark Lauby, (415) 855-2304

18–22
Acoustic Leak and Crack Detection Course
Eddystone, Pennsylvania
Contact: Richard Colsher, (215) 595-8870

19–20
Workshop: Distribution Cable
Atlanta, Georgia
Contact: Harry Ng, (415) 855-2973

21–22
Workshop: Distribution Cable
Kansas City, Missouri
Contact: Harry Ng, (415) 855-2973

25–28
1991 Symposium on Stationary NO_x Control
Washington, D.C.
Contact: Maureen Barbeau, (415) 855-2127

APRIL

2–5
International Conference: Improved Coal-Fired Power Plants
San Francisco, California
Contact: Susan Bisetti, (415) 855-7919

2–5
Transmission Line Design: ENVIRO, RNOISE, MULTIFlash, DYNAMP
Lenox, Massachusetts
Contact: Jim Hall, (415) 855-2305

8–12
Transmission Line Structural Analysis and Design: ETADS Hands-on Seminar
Haslet, Texas
Contact: Paul Lyons, (817) 439-5900

9–11
Radiation Field Control
Palo Alto, California
Contact: Lori Adams, (415) 855-8763

9–11
Railroad, Pipeline, and Transmission Line Compatibility
Evanston, Illinois
Contact: Jim Hall, (415) 855-2305

17–19
International Conference: Power Plant and Power System Training Simulators and Modeling
Miami, Florida
Contact: Pam Turner, (415) 855-2010

24–25
Power Plant Electric Auxiliary Systems
Princeton, New Jersey
Contact: Maureen Barbeau, (415) 855-2127

25–26
Magnetic Field Measurement
Lenox, Massachusetts
Contact: Greg Rauch, (415) 855-2298

25–26
1991 Utility Strategic Planning Forum
Baltimore, Maryland
Contact: Susan Bisetti, (415) 855-7919

MAY

1–3
Evaluation of Demand-Side Management Impacts
Chicago, Illinois
Contact: Bill LeBlanc, (415) 855-2887

1–3
International Symposium: Biological Processing of Coal
San Diego, California
Contact: Susan Bisetti, (415) 855-7919

7–9
Conference: Heat Rate Improvement
Scottsdale, Arizona
Contact: Pam Turner, (415) 855-2010

8
Security Enhancement Users Group
Baltimore, Maryland
Contact: Ram Adapa, (415) 855-8988

13–15
Utility Applications of Optical Sensing
San Francisco, California
Contact: Lori Adams, (415) 855-8763

JUNE

3–5
ETADS Experienced-Users Workshop
Haslet, Texas
Contact: Paul Lyons, (817) 439-5900

3–5
1st International ISA–EPRI Controls and Automation Conference
St. Petersburg, Florida
Contact: Arvind Agarwal, (415) 855-2773

3–7
Workshop: Distribution Cable
Indianapolis, Indiana
Contact: Harry Ng, (415) 855-2973

3–7
Workshop: Distribution Cable
Washington, D.C.
Contact: Harry Ng, (415) 855-2973

4–6
Conference: Cycle Chemistry in Fossil Fuel Plants
Baltimore, Maryland
Contact: Maureen Barbeau, (415) 855-2127

12–14
Upgrading Transmission Lines
Haslet, Texas
Contact: Dick Kennon, (415) 855-3211

16–19
Workshop: Radwaste
Boulder, Colorado
Contact: Carol Hornibrook, (415) 855-2022

17–21
Transmission Line Electrical Design: ACDCLINE
Lenox, Massachusetts
Contact: Jim Hall, (415) 855-2305

18–20
Workshop: Condensate Polishing
Scottsdale, Arizona
Contact: Lori Adams, (415) 855-8763

20–21
Seminar: Low-Level Waste Management and Radiation Protection
Boulder, Colorado
Contact: Carol Hornibrook, (415) 855-2022

24–26
1991 EPRI Technology Transfer Meeting
Palo Alto, California
Contact: Joanne Peterson, (415) 855-2716

26–28
Conference: Information and Automation Technology
Washington, D.C.
Contact: Pam Turner, (415) 855-2010

26–28
Power Plant Pumps
Tampa, Florida
Contact: Susan Bisetti, (415) 855-7919

JULY

16–18
Steam Turbine Generator Life Assessment and Maintenance
Charlotte, North Carolina
Contact: Tom McCloskey, (415) 855-2655

30–August 1
5th National Demand-Side Management Conference
Boston, Massachusetts
Contact: Bill LeBlanc, (415) 855-2887

SEPTEMBER

9–11
Expert Systems
Boston, Massachusetts
Contact: Susan Bisetti, (415) 855-7919

18–20
Conference: Fossil Plant Construction
Boston, Massachusetts
Contact: Pam Turner, (415) 855-2010

18–20
International Conference: Use of Coal Ash and Other Coal Combustion By-products
Shanghai, China
Contact: Dean Golden, (415) 855-2516

19–20
Magnetic Field Measurement
Lenox, Massachusetts
Contact: Greg Rauch, (415) 855-2298

25
ETADS Users Group Meeting
Dallas, Texas
Contact: Paul Lyons, (817) 439-5900

OCTOBER

8–11
Coal Gasification
San Francisco, California
Contact: Lori Adams, (415) 855-8763

8–11
PCB Seminar
Baltimore, Maryland
Contact: Maureen Barbeau, (415) 855-2127

15–18
Meeting Customer Needs With Heat Pumps
Dallas, Texas
Contact: Pam Turner, (415) 855-2010

15–18
Particulate Control
Williamsburg, Virginia
Contact: Susan Bisetti, (415) 855-7919

Authors and Articles


Stahlkopf


Machiels


Mann


Mulvaney


Pullen


Worledge

In Search of a National Energy Policy (page 4) was written by *Journal* senior feature writer Taylor Moore on the basis of interviews with senior energy experts from EPRI and its Advisory Council. ■

Probabilistic Risk Assessment: Prescription for Severe-Accident Prevention (page 16) was written by John Douglas, science writer, with technical information provided by members of EPRI's Nuclear Power Division.

Karl Stahlkopf directs the division's Safety Technology Department. Earlier, from 1980 to 1989, he headed its Systems and Materials Department. Stahlkopf came to EPRI in 1973 after seven years in the Navy, where he specialized in nuclear propulsion. A University of Wisconsin graduate, he also holds MS and PhD degrees in nuclear engineering from the University of California at Berkeley.

Albert Machiels took on management of the severe-accident program in 1990, having previously headed EPRI's external fuel cycle program. Before joining the Institute in 1982, he was an associate professor of nuclear engineering at the University of Illinois at Urbana and had also taught at the University of California at Berkeley. Before that, Machiels worked in the Materials and Molecular Research Division of Lawrence Berkeley Laboratory. He holds two engineering degrees from the Université de Liège in Belgium and an MS and a PhD in engineering from UC Berkeley. ■

Computer Gateway to EPRI (page 24) was written by David Boutacoff, *Journal* feature writer, with information from several EPRI staff members.

Marina Mann, director of EPRI's Information Technology Division, joined the Institute in 1984. Before coming to EPRI, she was vice president of central systems at Wells Fargo Bank. She also served as vice president of computer systems at the Federal Reserve Bank of San Francisco. Earlier in her career, Mann worked in the international pharmaceutical industry, where she was responsible for scientific, manufacturing, and cost accounting systems. Mann is a graduate of the University of New Mexico.

James Mulvaney, manager of the Electronic Technology Transfer Department, has been with EPRI since 1978, serving first as a planning analyst in the Planning and Evaluation Division, then as manager of end-user computing. Before joining EPRI he was an engineer with Long Island Lighting Company for 10 years. Mulvaney holds a BS degree in electrical engineering from Clarkson College of Technology, an MS in industrial management from the State University of New York at Stony Brook, and an MS in engineering economic systems from Stanford University.

Marguerite Pullen, EPRINET product manager, joined the Institute in 1989 to launch EPRINET in the commercial marketplace. In marketing the Institute's electronic communications tools, she draws on 25 years of experience in the development, implementation, training, support, and marketing of specialized computer systems. Pullen spent 12 years applying the technology to branch offices of stock brokerage firms and stock exchanges, and another 12 years applying personal computer technology in the institutional foodservice industry. She has a BS in mathematics from Michigan State University. ■

Update on Cold Fusion (page 34) was written by science writer John Douglas, with technical guidance from **David Worledge**.

Worledge, a program manager for nuclear power risk assessment, has worked for 20 years in the physics of nuclear power fuels and processes. He came to EPRI's Nuclear Power Division in 1981 after nearly eight years with the United Kingdom Atomic Energy Authority. Earlier at the UK Rutherford Laboratory, he worked on meson beam optimization for nuclear structure studies. Worledge holds a BS degree in physics and a PhD in nuclear physics, both from the University of Birmingham, United Kingdom. ■

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