Innovation and Industrial Productivity

ELECTRIC POWER RESEARCH INSTITUTE

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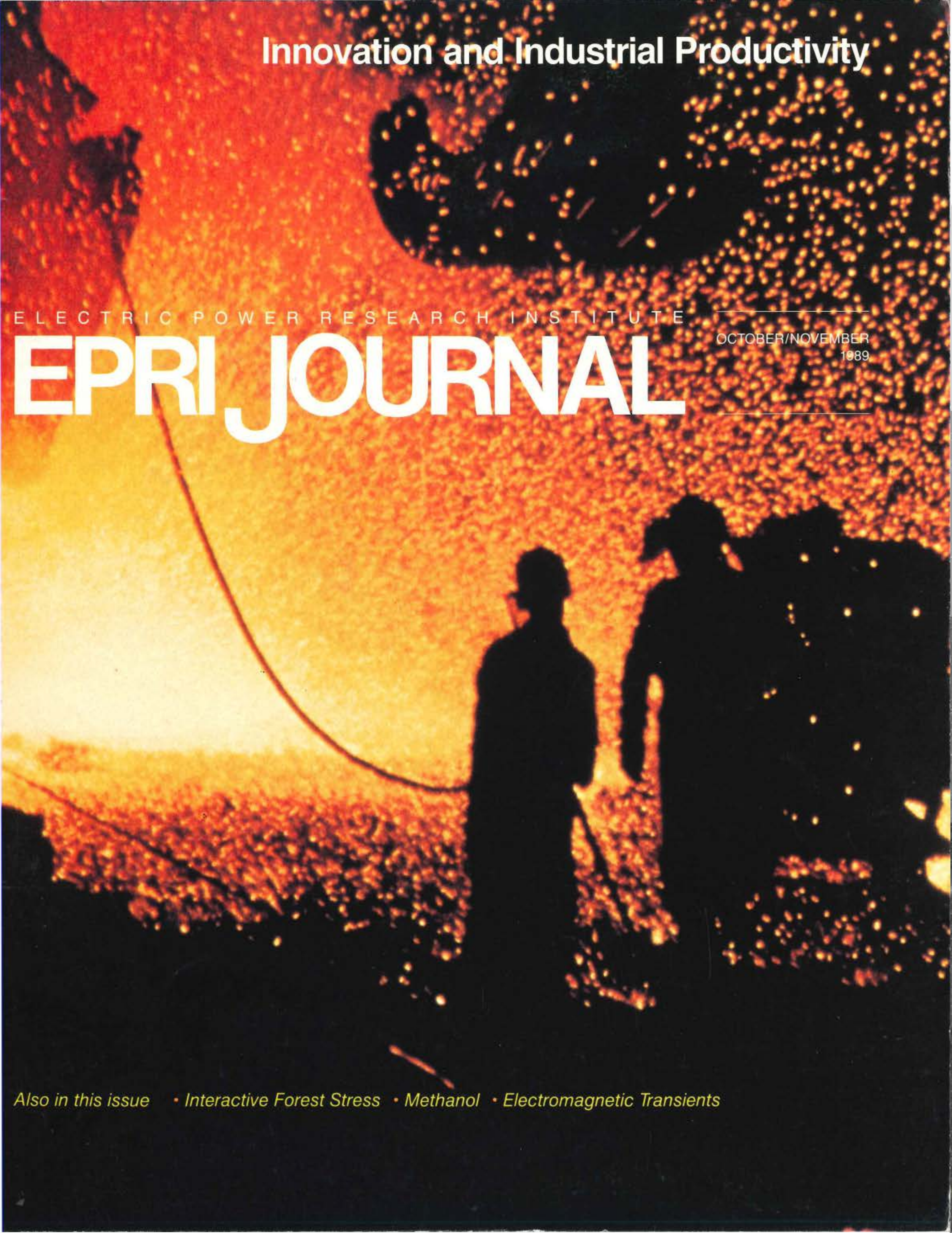

Also in this issue · *Interactive Forest Stress* · *Methanol* · *Electromagnetic Transients*

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Cover: Productivity-improving electrotechnologies have helped U.S. steelmakers regain a competitive position in the world market.

The New Industrial Imperative

As manufacturers in the United States strive to remain competitive in the world marketplace, electric utilities are placing new emphasis on preserving and expanding their industrial load base. The industrial sector, which accounts for 36% of total electrical load, is also inextricably linked to the loads of the residential and commercial sectors in many communities: when manufacturing companies fail, skilled workers may leave the area and nearby commercial concerns often must retrench or close.

This situation has led to a strengthened confluence of interests between utilities and their industrial customers. Manufacturers are looking for technologies that can increase productivity, lower costs, and improve product quality. Since these technologies are almost invariably electricity-driven, their application provides utilities with a unique opportunity to strengthen their industrial base and improve load factors. The result is a win-win situation for the utility and the customer.

To take advantage of this opportunity and carry out the ambitious technology transfer program it requires, utilities must find ways of working more closely with their industrial customers. Much of this responsibility will fall on utility marketing representatives, who face a formidable challenge. They must not only become familiar with many different types of manufacturing process, but also determine which electrotechnologies could be most advantageous in each case.

As discussed in this month's cover story, EPRI's Industrial Program is designed to assist utilities in this effort. Through its R&D application centers, the program fosters collaborative efforts by manufacturers and utilities to speed productivity-enhancing technology from the laboratory to the factory floor. In addition, the Affiliate Member Program provides utility marketing representatives with direct access to industrial products and services, including applications software that can be used both for choosing electrotechnologies to meet specific needs and for determining the potential effect of these technologies on a utility's load.

Sustaining industrial competitiveness over the long haul will require fundamental changes, including a long-term commitment to the development and adoption of new technologies. Today industrial R&D resources are increasingly constrained, and technology transfer is often haphazard. By helping their industrial customers identify technology opportunities, utilities can play a key role in fostering a renaissance of American manufacturing. EPRI's Industrial Program provides the framework for that effort.

I. Leslie Harry

I. Leslie Harry, Manager
Industrial Program
Customer Systems Division

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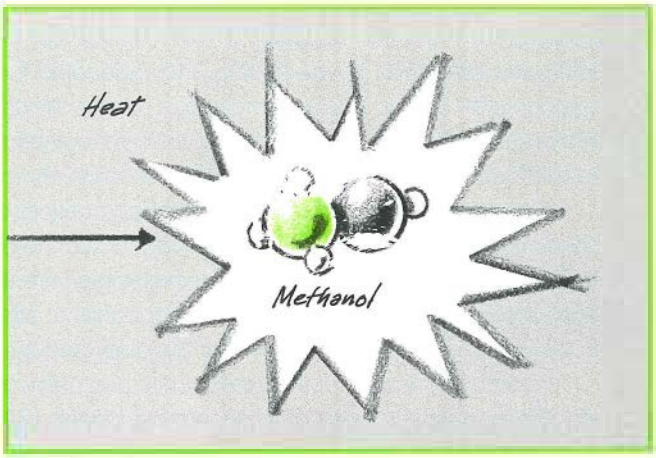

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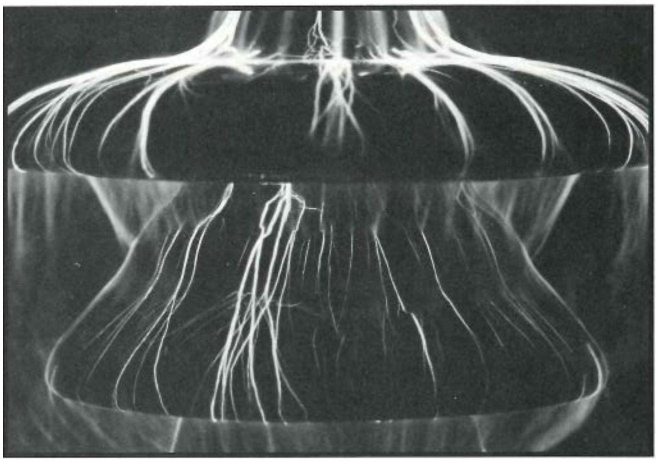

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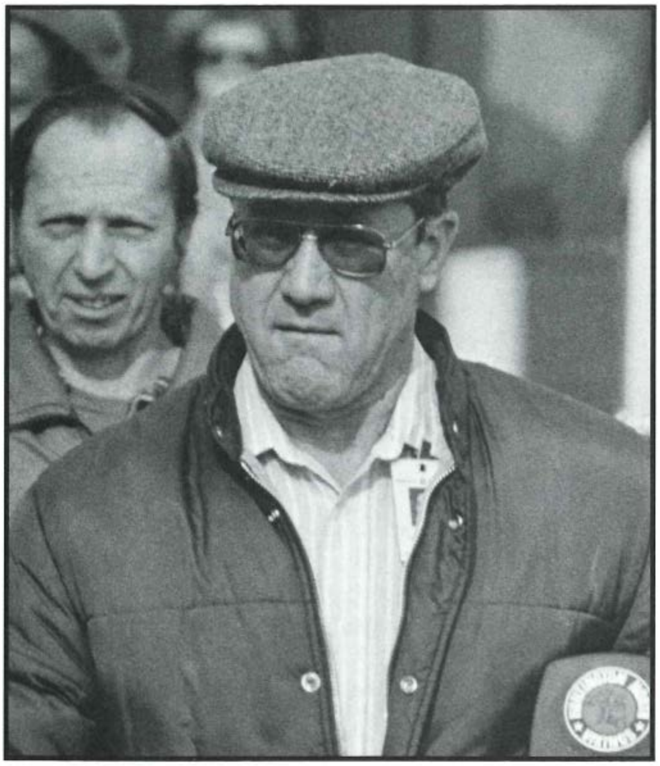

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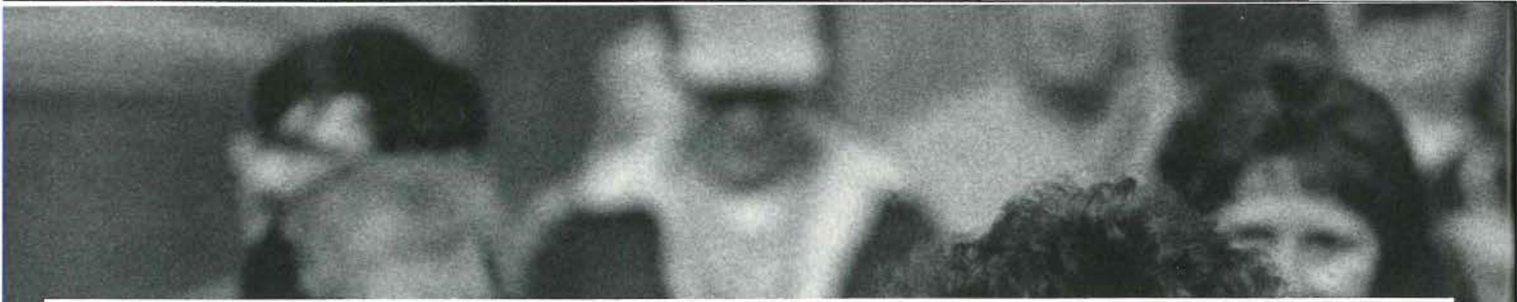


Productivity improvements are signaling a new vigor in key pockets of U.S. manufacturing, but technological innovation will be crucial to continuing industry's recovery over the long term.

After a long period of declining productivity, American industry shows promising signs of resharpening its competitive edge. The improvement has been particularly impressive in the manufacturing sector, where productivity has been growing faster over recent years than in any other major industrialized nation, except Japan. U.S. manufacturing productivity, in terms of output per unit of combined labor and capital input, increased fivefold in recent years—from an average of only about 0.5% during the 1973–1979 period to about 2.5% during the 1979–1986 period.

This much-needed recovery, however, may prove fragile. Although factories are now operating near full capacity, more than a third of the growth in labor productivity has come at the expense of lost jobs. Rising exports have helped the U.S. trade deficit, but much of the improvement has resulted from a steep depreciation of the American dollar. Inflation remains largely in check, but the national debt has more than doubled since 1982, reaching a level that now threatens the formation of domestic capital for investment.

Over the long term, industrial productivity depends more on overhauling outmoded operations and introducing new technologies than on one-time belt-tightening. Again, some improvements have been made, but much more needs to be done. In its recent study, *Made in America,* the MIT Commission on Industrial Productivity reports: "In such areas as product quality, service to customers, and speed of product development, American companies are no longer perceived as world leaders, even by American consumers. There is also evidence that technological innovations are being incorporated into practice more quickly abroad, and the pace of invention and discovery in the United States may be slowing."

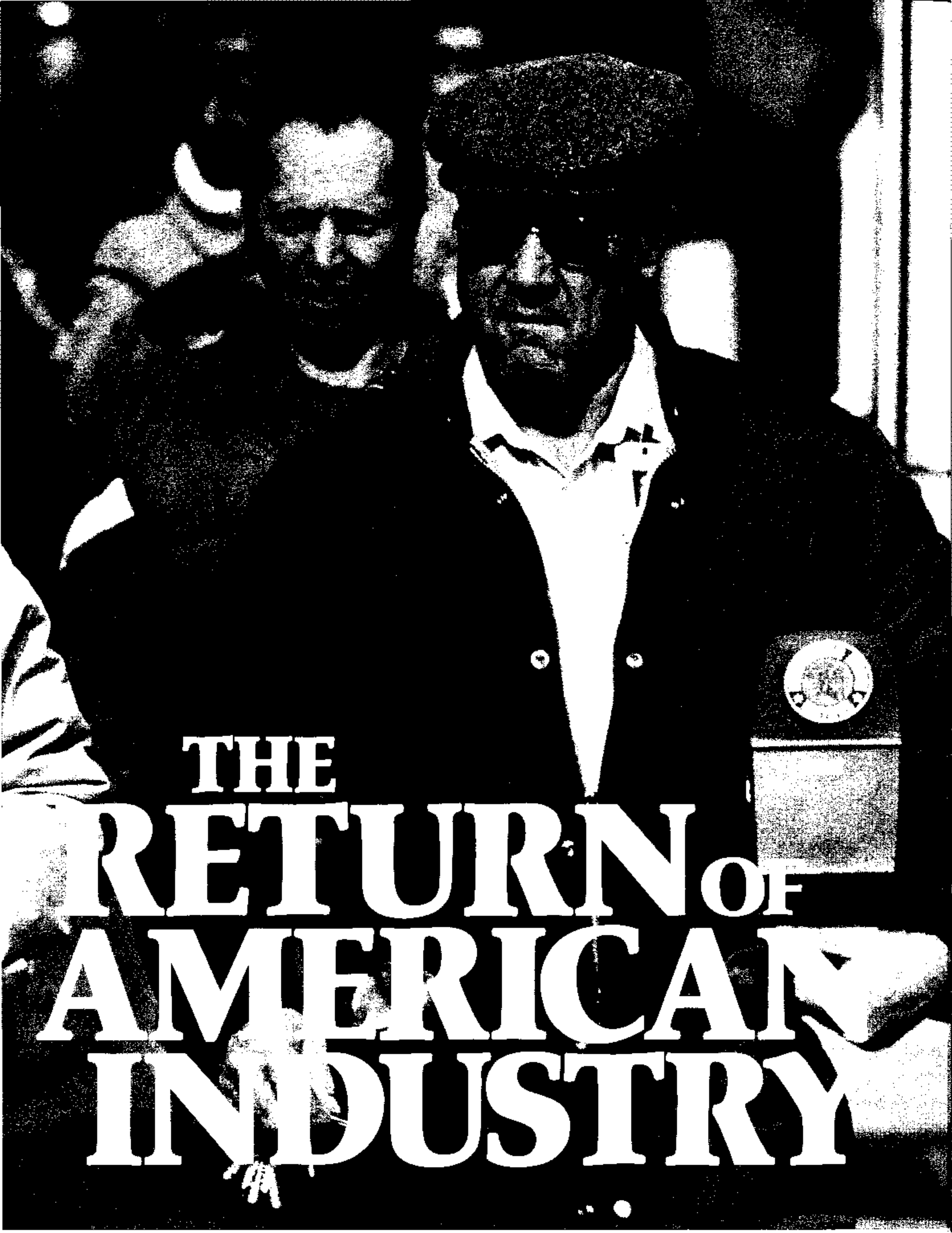
More than two-thirds of U.S. manufacturing output must now face direct foreign competition. If the cost and quality of American goods are to become more attractive, new ways to speed introduction of the latest technological advances into both factories and products will be especially needed. Electric utilities can play a major role in this effort by helping their industrial customers improve productivity through the increased use of highly efficient electrical technologies. The Industrial Program of EPRI's Customer Systems Division offers a unique opportunity for both utilities and manufacturers to become more familiar with such technologies.

Postindustrial mythology

The current effort to revive industrial productivity is based on two key assumptions: that manufacturing is still important to the American economy, and that long-term productivity gains must be based on technological innovation rather than on inherently limited cost-cutting expedients. The first of these assumptions—once accepted as obvious—has become the subject of considerable debate, as the contribution of manufacturing to the gross national product has declined to less than one-fourth and its share of workers to less than one-fifth. The Reagan administration made a particularly strong statement of this point of view in a report to Congress on trade: "The move from an industrial society toward a 'postindustrial' service economy has been one of the greatest changes to affect the developed world since the Industrial Revolution."

More recently, however, the importance of manufacturing is being reemphasized. In the book *Manufacturing Matters: The Myth of a Post-Industrial Economy,* Stephen S. Cohen and John Zysman of the University of California at Berkeley argue that a "direct linkage" exists between many service jobs and manufacturing production. Although immediate employment in manufacturing accounts for only about 21 million jobs, the authors estimate that two to three times as many Americans—most considered as service workers—depend directly on manufacturing for their livelihood. "If manufacturing goes, these service jobs will go with it," they conclude.

The MIT commission agrees, attacking head-on the proposition that a transition from manufacturing to services is an inevitable and desirable stage in economic development. "We think this idea is mistaken. A large continental economy



THE RETURN OF AMERICAN INDUSTRY

like the United States will not be able to function primarily as a producer of services in the foreseeable future," the commission's report states bluntly. "The United States thus has no choice but to continue competing in the world market for manufactures."

The ability to compete depends, of course, on a variety of factors. Some of these, such as the overall health of the American economy, are beyond the influence of individual companies. Several other factors that affect productivity can be controlled directly by manufacturers— including shutdown of obsolete facilities, retrenchment to the most profitable niches of a market, and introduction of new technology. In today's increasingly technical world, however, cost cutting without innovation amounts to retreat; long-term survival depends on finding new ways to develop and use technology.

A lesson from steel

Recent experience in the steel industry illustrates vividly how American companies are attempting to increase productivity. Faced with increased competition from overseas and a steady loss of market share, domestic steel companies went through a wrenching transformation between the mid-1970s and mid-1980s. As steelmakers cut costs, closed inefficient plants, and reduced overall capacity by about 28%, an estimated two-thirds of the jobs in the industry may have been lost.

As a result of these drastic changes, productivity has soared. The average cost of a ton of steel in the United States has fallen from \$550 to \$490, while Japanese costs have been rising. U.S. steel exports nearly doubled last year and may double again this year, according to Elizabeth Bossong, formerly manager of economic research at USX Corp. The average labor required to make a ton of steel from ore in an integrated mill has been reduced from about 10 man-hours in 1982 to less than 6 man-hours now, she says, with some individual plants doing considerably better.

In addition to the dramatic cost cutting and the declining dollar, Bossong cites the adoption of new technology as an important factor in the revival of productivity. Specifically, continuous casting has largely replaced the older practice of casting and then reheating separate ingots. A decade ago, continuous casting produced only about 16% of raw steel output; now it is responsible for more than 60%.

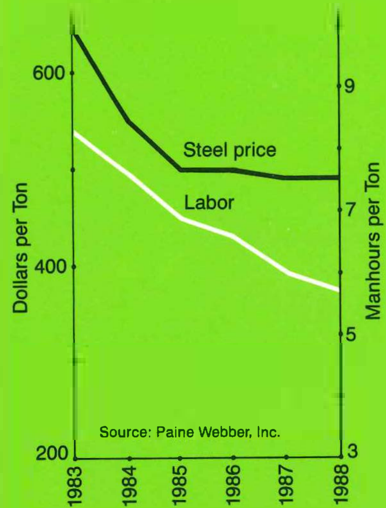
"Since 1973 [U.S. economic] growth has slowed about 2.8%, and productivity has dropped by almost two-thirds, to only 1.1%," Bossong recently told the Steel Survival Strategies Forum in New York. "What we need desperately in the country is to get those productivity numbers growing once again at something like 2.9%—certainly back to 2%—if we're going to achieve the kind of living standard potential that we used to assume was our birthright."

The importance of technology in the improvement of productivity can be seen in other industries as well. The chemical and aircraft industries, for example, both remain world leaders in technology and enjoy a healthy trade surplus. To maintain their technological advantage, both have recognized the value of collaborative research. Joint R&D programs have been established at several universities by leading chemical companies, and the Aerospace Industries Association is coordinating research by private companies, the government, and universities aimed at developing eight key technologies needed for the 1990s.

By contrast, technological weakness continues to devastate the machine tool and consumer electronics industries. As machine tools made a rapid transition to electronic controls, American manufacturers fell behind their Japanese and West German counterparts. Although many of the technologies involved in consumer electronics were originally developed in the United States, foreign

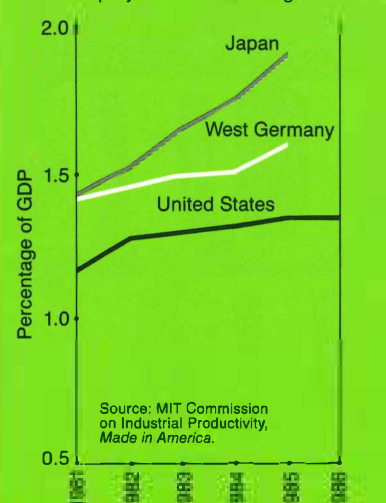
Industrial Productivity Is Up . . .

Steel is a startling example, with rising productivity cutting the U.S. price by nearly 25% in five years. Manpower reduction has been the big lever, more than 30% in the same period.



. . . But Industry's R&D Investment Is Not

The United States lags behind its major international competitors in R&D investment priority. Labor cuts must give way to technology innovation if markets and employment are also to grow.



companies have applied them more aggressively. Both industries have now established collaborative R&D efforts to help them catch up, but the programs remain relatively small.

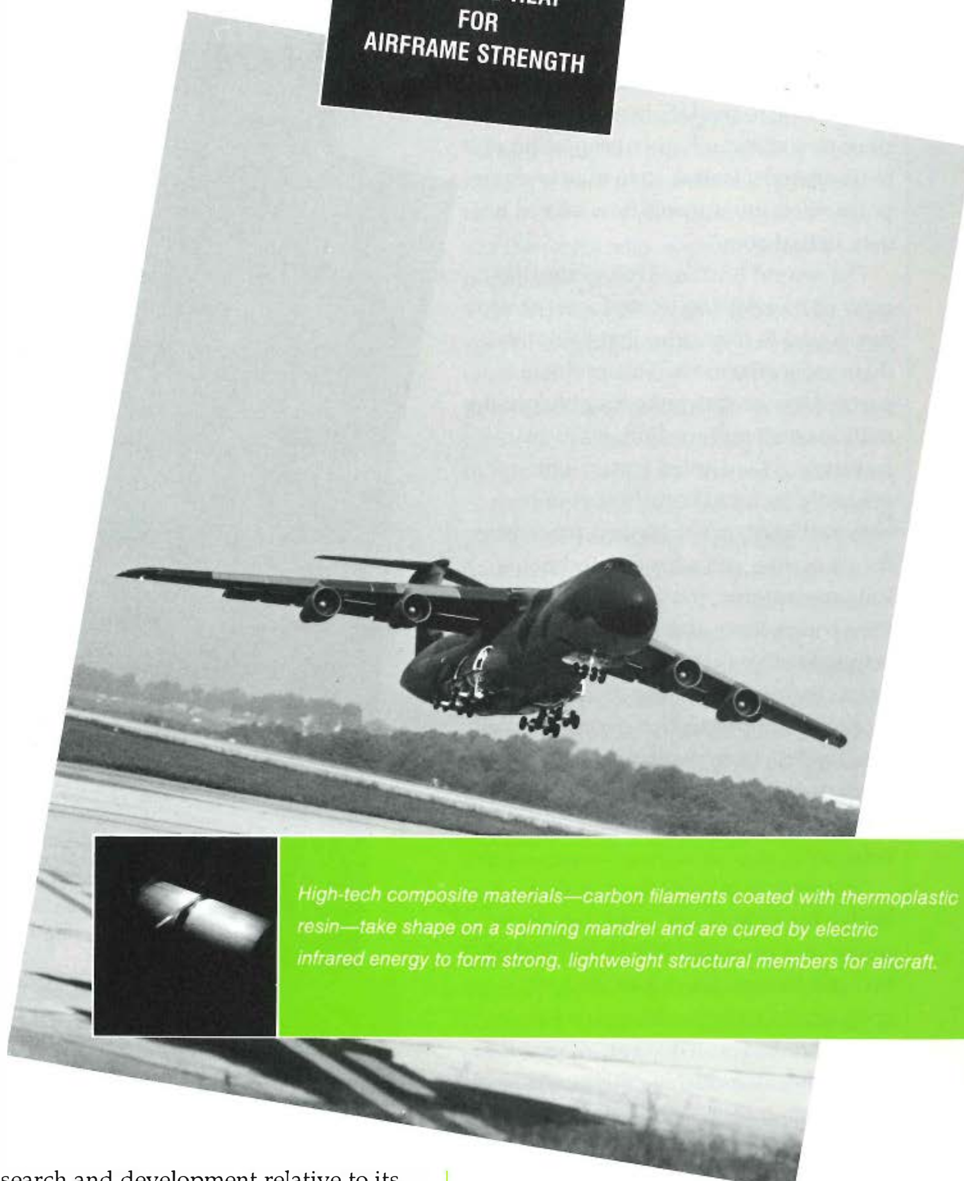
Needed: A bridge for technology

Many of the new technologies that are boosting the productivity of American industry involve the increased use of electricity, because of its unique advantages in automation and precise delivery of energy. "In manufacturing, the name of the game is time and temperature," says Les Harry, manager of EPRI's Industrial Program. "Electrotechnologies give you more flexibility to alter the two—shortening production times, improving product quality, reducing energy consumption by heating products more exactly, and often reducing environmental problems at a factory as well."

Steelmaking again provides good examples of how electric power offers opportunities to increase productivity by fundamentally changing its time and temperature components. Arc furnaces provide an intense concentration of heat that enables steel to be produced quickly in small quantities from recycled scrap. The result has been a steady rise of "mini-mills," which compete directly with large, integrated mills for the high end of the steel market. Continuous casting uses electrically driven and controlled equipment to eliminate reheating steps, which consume both time and energy. High-power lasers and electron beams have opened up new applications in welding by delivering energy with unprecedented precision. And very high temperature plasmas, ionized gases that can conduct an electric arc, may eventually provide a way to produce iron from ore directly, without the need for coke or a blast furnace.

Two hurdles, however, are impeding the introduction of advanced technologies into wider industrial practice. The first of these results from America's declining commitment to industrial research and development relative to its international competitors. Industry-funded R&D in this country has leveled off at about 1.3% of gross domestic product; in comparison, the figures for West Germany and Japan are about 1.6% and nearly 2%, respectively, and both of these are still growing rapidly. At the same time, government-sponsored R&D in the United States remains largely defense-related and has become less likely to contribute new technologies for industry.

INFRARED HEAT FOR AIRFRAME STRENGTH



High-tech composite materials—carbon filaments coated with thermoplastic resin—take shape on a spinning mandrel and are cured by electric infrared energy to form strong, lightweight structural members for aircraft.

"Military research and development no longer have the spin-off effect on the civilian sector of the economy that they did in the period when computers and microelectronics were developing," according to a recent Brookings Institution study, *Restructuring American Foreign Policy*, sponsored by Carnegie Corp. of New York. "U.S. businessmen now increasingly complain that American innovations in basic science and technology are being commercialized abroad," the study concludes. "These industrial rivals, moreover, have come to undertake their own technical investments in amounts comparable to the U.S. investment, and since they direct a higher proportion of it to commercial [rather than military] purposes, their investments now exceed our own in that area."

The second hurdle involves the difficulty of transferring technologies already developed to industries that could use them most effectively. This problem is particularly acute for the roughly quarter million small and medium-sized manufacturers in the United States, which generally lack R&D capabilities of their own and even an established procedure for surveying and adopting technological innovations. At a time when many of their competitors around the world are actively seeking out the best available technologies and putting them to use in more flexible production systems, many smaller American companies need help to catch up. Electric utilities are in an ideal position to provide some of this help.

"An electric utility can provide a bridge for technology," says Tom Byrer, senior vice president of Battelle, Columbus and former director of the EPRI-sponsored Center for Materials Fabrication, who draws on 30 years of experience in heavy industry. "Suppose a small firm needs a new cutting tool and is trying to decide between a laser, a water jet, and a saw. Or suppose they're having trouble integrating a new piece of equipment into their production line. Often they don't know where to go. We say, 'Call your utility.' An electric utility with a good industrial program is in a position to make this a win-win situation: the industrial customer modernizes; the utility keeps its load."

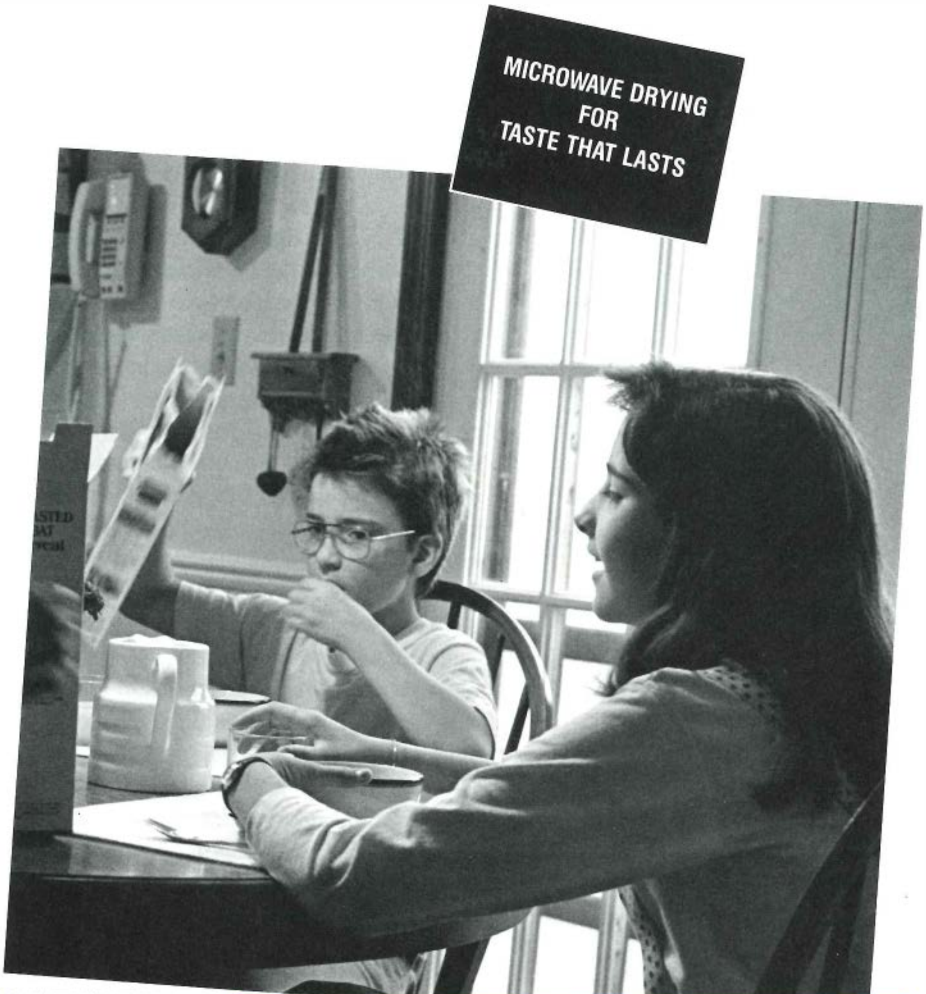
Automobile engine blocks are cast with new precision and economy in foundries that use an electric plasma cupola to melt scrap iron and control the chemistry of steel.

PLASMA TORCH FOR STEEL ECONOMY

EPRI as catalyst

EPRI's Industrial Program is aimed at helping selected industries overcome the two hurdles facing wider application of advanced electrotechnologies—the need for new resources focused on industrial R&D and the lack of sufficient technology transfer from lab to factory. In this endeavor, the Institute functions primarily as a catalyst. The Industrial Program brings together academic scientists, equipment vendors, and potential industrial customers from a variety of fields to form the critical mass required to complete specific electrotechnology development tasks. The program also involves work with electric utilities to more widely disseminate vital information on the manufacturing applications of electrotechnologies.

"When we began the Industrial Program, our first task was to find some way to get our arms around this huge sector of the economy," recalls Les Harry. "Just consider what a wide range of



Fast dehydration in a vacuum chamber yields apple (or other fruit) slices that have the taste, texture, and nutrition of the fresh fruit and are ready for packaging right along with the breakfast cereal itself.

products and manufacturing processes there are. We had to spend a good deal of time just sorting through things—characterizing technologies, analyzing industry structure and trends, and identifying new end-use applications of electricity."

Out of 27 electrotechnologies initially identified as having important potential for improving industrial productivity and impacting utility load, 9 were chosen to receive major emphasis during the next stage of the program. These were judged to show outstanding potential for growth because they provide better ways of heating and drying materials, separating components of a liquid mixture, or transferring heat between different stages of an industrial process.

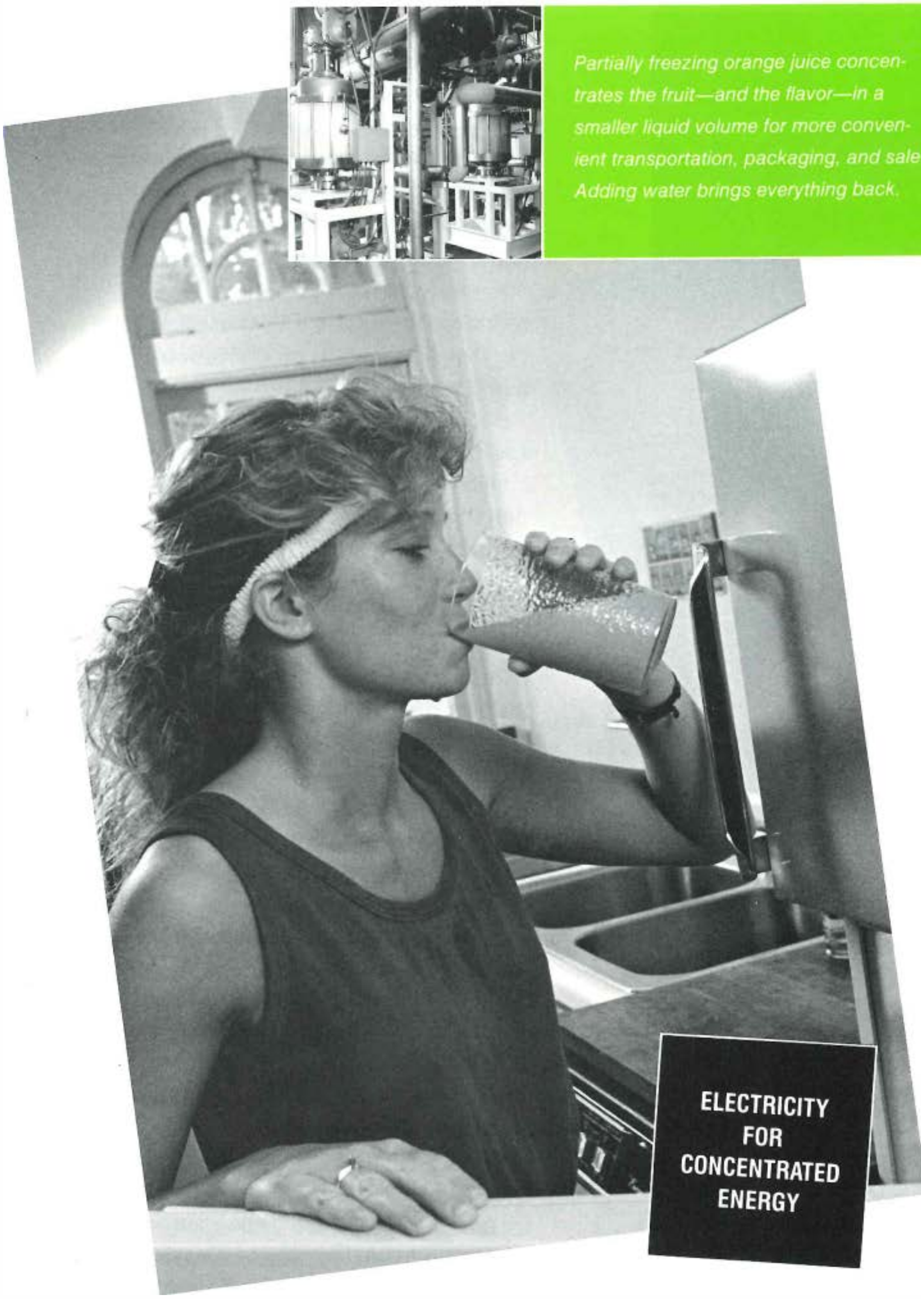
"To develop these promising technologies, we embraced the concept of establishing R&D application centers, for basically three reasons," according to Harry. "First, they provide leverage of EPRI resources, both dollars and manpower. Second, by giving each center its own advisory council composed of representatives from industrial companies, trade associations, utilities, and others, we were able to ensure broad credibility. Finally, the centers provide a badly needed infrastructure for communications and tech transfer—a new means of packaging the technological products, you might say."

So far, two fully active centers and one special coordinating office have been established. The Center for Metals Production (CMP) was established in 1984 at Carnegie-Mellon University in Pittsburgh. The Center for Materials Fabrication (CMF), originally called the Center for Metals Fabrication, began in 1983 at Battelle, Columbus Laboratories in Columbus, Ohio. And in 1988 the Process Industries Coordination Office (PICO) was launched, also at Battelle, Columbus. (The Power Electronics Applications Center, originally a part of EPRI's Industrial Program, is now part of the Power Electronics and Controls Program, with applications extending to the commercial and residential sectors as well as manufacturing.)

Production of metals

Primary metals production, which accounts for about 19% of manufacturing electricity consumption, is generally the province of relatively large, long-established companies. Through the Center for Metals Production, EPRI works with these firms and their trade associations to improve the productivity and efficiency of electrotechnologies in three basic areas: melting and casting, rolling and finishing, and electrolytic processing.

The various industrial segments involved in metals production have quite different needs, which are reflected in CMP's collaborative research on electrotechnologies. The steel industry, for example, is going through a major restructuring, in which electric arc furnaces that



Partially freezing orange juice concentrates the fruit—and the flavor—in a smaller liquid volume for more convenient transportation, packaging, and sale. Adding water brings everything back.

ELECTRICITY FOR CONCENTRATED ENERGY

start with scrap are steadily gaining market share at the expense of integrated, ore-to-metal operations. A major problem with arc furnaces is the dust they generate, recently classified as hazardous by the Environmental Protection Agency. CMP, in collaboration with 22 steel companies, has sponsored demonstrations of two dust treatments—one using a flame reactor and the other a plasma furnace—to render the dust into a nonhazardous slag while recovering usable zinc and lead.

CMP analyses have indicated that little can be done from a technological standpoint to return aluminum production to this country, since other factors, such as the value of the dollar, tend to predominate. Research emphasis has therefore been placed on improving domestic casting and mill operations. Induction heating and electromagnetic casting, for example, provide higher yields and allow for more automatic operation.

Foundries have been particularly hard hit by foreign competition and environmental restrictions. More than 500 foundries have closed in the United States since 1980. To help foundries remain competitive, CMP has opened an office in Chicago dedicated to assisting EPRI members and their foundry customers. CMP also helped sponsor the development of plasma-assisted cupola technology that can reduce production costs, facilitate quick changes in metal chemistry, and lower emissions. The first commercial facility based on this technology, a 9-MW facility, has recently been installed at the General Motors foundry in Defiance, Ohio.

"Metals production companies have increased their bottom-line profit in recent years, but it's not clear whether underlying problems have been addressed sufficiently," says Bob Jeffress, EPRI project manager for both CMP and CMF. "Companies are cutting back their own research and buying technologies from foreign suppliers. What EPRI is trying to do through its collaborative R&D program is provide opportunities to develop and demonstrate technology in this country in cost-effective applications."

Materials fabrication

In contrast to metal producers, metal and nonmetal fabricators tend to be relatively small firms that belong to many different trade associations. Their combined share of the manufacturing electric power load is about 33%. In addition to work with metals, the scope of the Center for Materials Fabrication has been expanded to include plastics, ceramics, composites, and wood. The current focus of CMF research involves a variety of electrotechnologies related to materials heating.

Dielectric heating uses radio-frequency fields and microwaves to transfer energy directly into materials—a principle used in ordinary kitchen microwave ovens. The result is faster, more uniform heating throughout the entire thickness of a material, which often leads to higher-quality products at lower cost. To explore new uses for dielectric heating, CMF is supporting a research program at the University of Texas that includes projects on the drying of plastics, gypsum wallboard, and decorative wall tiles. Also, preliminary trials in microwave sintering of new high-tech ceramics are getting under way at Ceramatech.

Infrared heating is being explored as an alternative to using a gas-fired autoclave oven in the consolidation of thermoplastic composites—lightweight materials containing graphite that are being used increasingly in aircraft design. CMF-sponsored tests at Lockheed Aerospace Systems have shown that infrared heating produces composite materials that are 9% stronger and 5% stiffer than those prepared in autoclaves, and the process requires only one-fourth to one-third the labor. CMF is also working with Kelsey Hayes on infrared treatment of cast aluminum wheels, which is expected to provide 50% savings in energy and labor and a 90–95% reduction in curing time, compared with conventional gas furnaces.

Induction heating involves the generation of eddy currents in conducting materials by applying an alternating magnetic field. The depth and rate of heating can be varied by changing the frequency and strength of the field. Following two years of laboratory and economic analysis on the use of induction heating to treat stainless steel sheet, CMF and Allegheny Ludlum are initiating a commercial demonstration of the process. This project is expected to show that the cost of heat treatment of stainless sheet can be reduced $12–35 per ton by using induction technology. By the turn of the century, this new technology could replace conventional heat treatment for more than half the stainless sheet being manufactured.

Exactly timed infrared energy, targeted from banks of emitters clear across the web, ensures a consistent moisture content throughout each roll of paper manufactured for fine-quality print production.

ELECTRIC PRECISION FOR PAPER MOISTURE CONTROL

"Most small companies alone can't afford to risk capital on innovation; they want to see documented demonstration of a technology before making a commitment," Jeffress points out. "Our strategy is to facilitate collaborative project development and demonstration that can include both manufacturers and equipment vendors. In some cases, we work first with large manufacturers that have the technical and financial resources to participate in technology development. Such demonstration may then provide the opportunities and assurances small manufacturers need to commit their resources to implement the technology."

Process improvements

Process industries—including textiles, paper, chemicals, food, and petroleum—use nearly half the electricity consumed by the manufacturing sector. About 80%

Card-Carrying Members in Customer Service

AMP, the Affiliate Member Program of EPRI's Customer Systems Division, offers an inside track for electrotechnology transfer to industrial electricity users. Utility customer service representatives share R&D progress and insights through timely workshops, software, and publications, as well as a toll-free telephone service.

Alabama Electric Cooperative, Inc.
Alabama Power Co.
Arizona Public Service Co.
Arkansas Power & Light Co.
Baltimore Gas & Electric Co.
Bonneville Power Administration
Carolina Power & Light Co.
Central Hudson Gas & Electric Corp.
Central Illinois Public Service
Central Power & Light Co.
Central & South West Corp.
Chattanooga Electric Power Board
Cincinnati Gas & Electric Co.
Cleveland Electric Illuminating Co.
Commonwealth Edison Co.
Consolidated Edison Co. of New York, Inc.
Delmarva Power & Light Co.
Duke Power Co.
Duquesne Light Co.
East Mississippi Electric Power Association
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Florida Power Corp.
Florida Power & Light Co.
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Illinois Power Co.
Indianapolis Power & Light Co.
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Memphis Light, Gas & Water Division
Metropolitan Edison Co.

Midwest Energy, Inc.
Minnesota Power
Mississippi Power Co.
Missouri Public Service
New England Power Service Co.
New York Power Authority
Niagara Mohawk Power Corp.
Northeast Utilities
Northern Indiana Public Service Co.
Northern States Power Co.
North Western Electric Coop, Inc.
Oglethorpe Power Corp.
Ohio Edison Co.
Oklahoma Gas and Electric Co.
Owen County Rural Electric Coop Corp.
Pacific Gas and Electric Co.
Pennsylvania Electric Co.
Pennsylvania Power & Light Co.
Public Service Co. of Colorado
Public Service Co. of Oklahoma
Public Service Indiana
Puget Sound Power & Light Co.
Richland Energy Services Department
Rochester Gas & Electric Co.
Sacramento Municipal Utility District
Salt River Project
San Diego Gas & Electric Co.
Savannah Electric and Power Co.
Sierra Pacific Power Co.
Snohomish County Public Utility District No. 1
Southern Company Services, Inc.
Southwestern Electric Power Co.
St. Joseph Light & Power Co.
Tennessee Valley Authority
Toledo Edison Co.
TU Electric
Union Electric Co.
Virginia Power
West Texas Utilities Co.
Wisconsin Electric Power Co.
Wisconsin Power & Light Co.
Wisconsin Public Service Corp.

of this electric power is used in motor drives, including those that drive heat pumps, freeze concentration equipment, and membrane separators. These three application areas are the focal point for research funded by the Industrial Program in cooperation with a variety of industry groups. The Process Industries Coordination Office has been established to facilitate this interaction and technology transfer.

Heat pumps can greatly increase the effiency of some industrial processes by taking waste heat from one stage and using it in another. In a petroleum refinery, for example, a heat pump can be used to transfer heat from the top of a distillation tower to the bottom, thereby eliminating a fuel-burning reboiler and reducing pollution. EPRI is conducting 15 case studies on industrial heat pump applications, using a general analytical method (called "pinch technology") for optimizing heat and power use in complex processes. Such process integration is expected to result in a 20–40% energy reduction in many applications, with a one- to two-year payback period.

Freeze concentration can be used to replace heat evaporation in preparing certain foods and in treating wastewater. EPRI is sponsoring a pilot plant demonstration of freeze concentration of milk in cooperation with Dairy Research, Inc. (DRINC). This process dramatically lowers energy costs, compared with conventional steam-driven evaporators, and leads to better-tasting reconstituted milk and potentially new products. The Industrial Program is also examining freeze concentration of wastewater in a metal-plating facility, an application that includes the recovery of valuable raw materials.

Membrane processes use electric pumps to force liquid mixtures through a permeable barrier, which filters out selected components. Membranes have been used commercially for the past 15 years in such applications as clarifying fruit juices and desalinating seawater—providing a cost-saving alternative to energy-intensive evaporation and distillation. Developments in this rapidly growing field are currently being monitored, especially work on improving membrane life, reducing fouling, and increasing the volume throughput.

In addition to research on motor-driven applications, the Industrial Program is exploring novel uses for dielectric heating. In a project cofunded with several California utilities, California State University at Fresno used microwave heating in a vacuum to produce a nutritious, crunchy new snack food—grape puffs—that retains the shape, color, and taste of the original grapes. The technique is now being tried on a variety of other fruits and vegetables.

"Meeting the needs of such a diverse group of industries is very demanding, and we are currently reassessing how PICO should be structured," says project manager Ammi Amarnath. "Several process industries have strong regional attachments, such as textiles in the Southeast and petroleum and chemicals in the Middle South."

Future directions

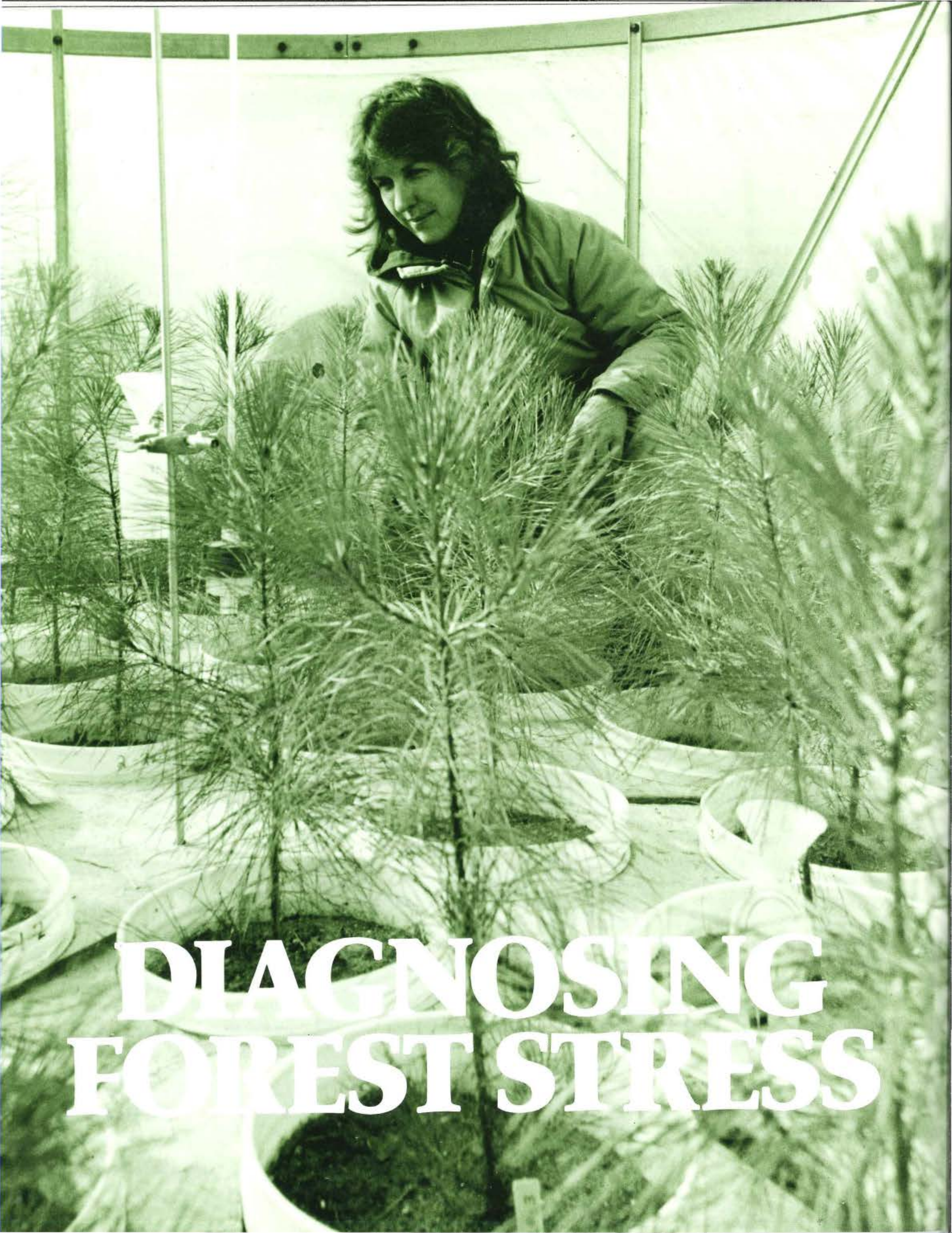
Les Harry believes that EPRI's Industrial Program has come a long way toward meeting the needs expressed by manufacturers and utilities when it was just getting started. A major task for the next five years, he says, is "to work on integrating our various activities. First, we'll want to look at ways of integrating industrial activities, utility demand-side planning needs, and rate structures (as incentives for adopting economically efficient electrotechnologies). Second, the increasing use of computer controls, adjustable-speed drives, and other electrotechnologies gives rise to opportunities in power electronics. Thus we will need increased coordination with the Power Electronics and Controls Program. Third, commercial and industrial activities are becoming more integrated. Consider food refrigeration, for example: essentially the same technology is used in commercial warehouses and manufacturing plants, and more companies are engaging in both storage and processing activities. Our efforts should reflect these developments."

To help utilities take better advantage of rapidly changing developments, the Industrial Program recently established the Affiliate Member Program (AMP). The specific objective is to provide utility marketing and customer service managers with improved access to information about the products and services of the Industrial Program. Affiliates receive monthly mailings about ongoing activities, announcements of opportunities to collaborate in demonstration projects, software to enhance the targeting of electrotechnologies toward the best markets, and additional support in the form of workshops and a special phone hotline. So far, 83 of EPRI's largest 125 members have signed up for AMP.

To help utilities identify target markets for electrotechnology applications in their service territories, the Industrial Program has produced a new software tool for utility marketing and customer service staff. The Industrial Market Information System (IMIS) can be used on a personal computer to develop lists of industry segments or specific customers that meet particular screening criteria. IMIS then estimates the load impacts that would result if these customers adopted certain electrotechnologies.

"Our biggest challenge is how to make electrotechnologies more accessible," Harry concludes. "We're trying to meet that challenge by sponsoring research and information gathering at the application centers, targeting results to key utility marketing people through AMP and IMIS, and increasingly integrating the Industrial Program with other EPRI and utility initiatives." ■

This article was written by John Douglas, science writer. Technical background information was provided by Les Harry, Bob Jeffress, and Ammi Amarnath of the Customer Systems Division.


DIAGNOSING
FOREST STRESS

Researchers are looking for the larger picture in forest health—not just the effects of one or two isolated pollutants, but an integrated model of how forests respond to complicated combinations of natural and man-made stresses.

On a warm, sunny day in the fall of 1987, Patrick J. Temple, an assistant research botanist at the University of California at Riverside, took 2200 ponderosa pine seedlings, each in its own pot, to the Sequoia National Forest in California's Sierra Nevada. He had taken considerable care to protect the seedlings, since they were destined to be subjects in a large integrated effort to comprehend how plants react to multiple stresses. As a member of a research team undertaking a highly comprehensive study of forest decline, Temple was excited at the prospect of blazing a new trail: the experiment would simulate, for the first time, actual conditions where many forces—both natural and man-made—attack trees simultaneously.

At the experimental field site, generators were set up to create ozone (by means of electric arc discharge, similar to the way lightning creates ozone during a thunderstorm) to be dispensed into exposure chambers containing plants. Large vats were filled with water acidified with nitric and sulfuric acids to be sprayed on the plants by a rain nozzle in the center of the open-top chambers surrounding the seedlings. And finally, irrigation lines were laid that could be shut off to subject the plants to water deprivation.

Ozone, acid precipitation, and drought are only three of the many possible stresses that can affect Sierra forests today. Surrounding the experimental seedlings are primeval stands of ponderosa pine, sugar pine, white fir, and incense cedar, as well as the famed giant sequoia, some of which are 2000 to 3000 years old. Over the years, all these trees have survived the pestilent onslaughts of fire, drought, parching sun, erosion, and bark beetles and other insects. More recently, air pollution and soil pollution have begun to threaten them as well. "Perhaps the ultimate threat today is global climate change," Temple says. "If California becomes warmer and drier, trees adapted to a cooler and wetter climate, like the giant sequoia, may fail to reproduce."

None of these assaults occurs in isolation. Rather, the stresses on trees interact in infinitely varied combinations.

Forces of attack

To examine all the forces—man-made and natural—threatening our forests, EPRI has assembled a team of scientists from across the country in one of the biggest and most ambitious efforts ever undertaken to study the effects of air quality and environmental change on plant life. Temple is one of over a dozen leading scientists, each with a unique expertise, from almost as large a group of prestigious institutions, who are attempting to develop general theoretical models that predict how interacting stresses affect vegetation.

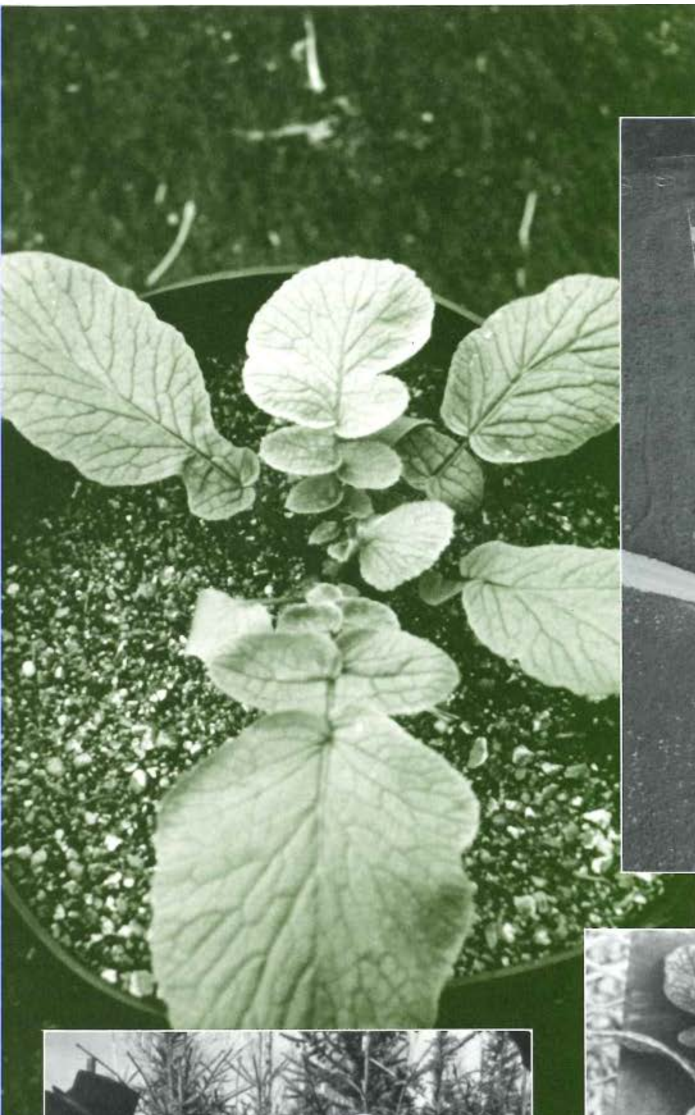
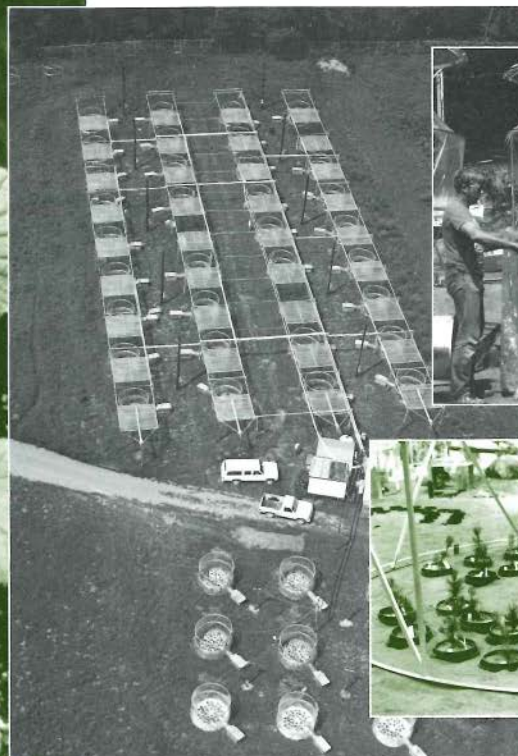
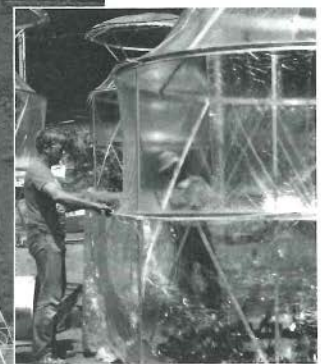
The program, called ROPIS (response of plants to interacting stresses), was initiated in 1985 under the direction of Dr. Robert A. Goldstein, a systems ecologist and EPRI program manager.

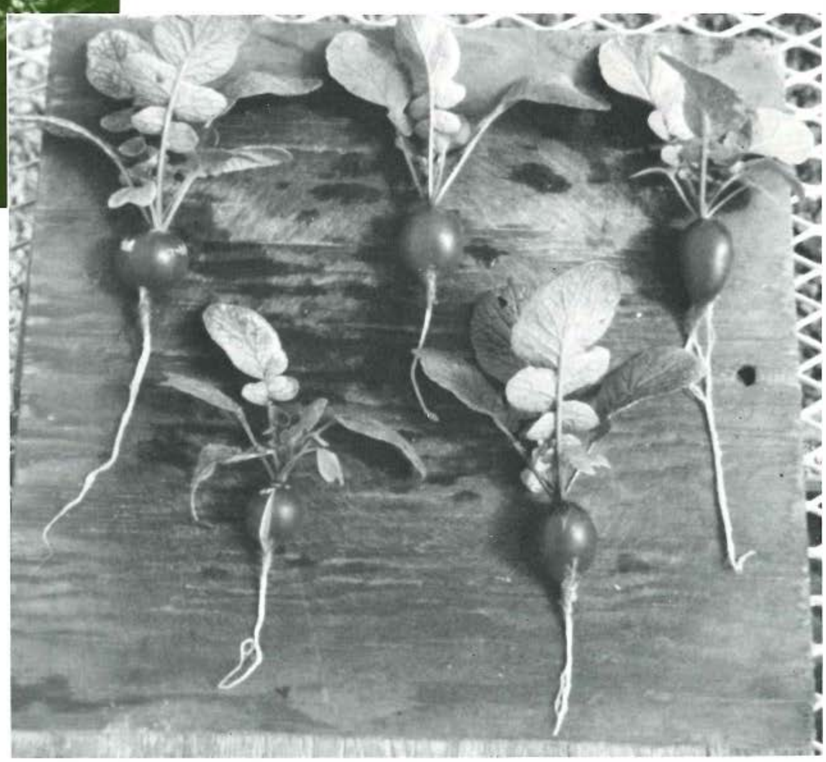
"Many people think of ROPIS as an acid rain program," Goldstein says. "But that's not the case. ROPIS is as applicable to ozone pollution or climate stress as it is to acid rain." Goldstein explains that earlier research concerning the impact of air pollution on vegetation had been highly empirical and compartmentalized, using a dose-response approach to consider the effects of individual stressors, one at a time. "If you were worried about how plants might respond to ozone, you exposed a plant to different concentrations of ozone and observed what happened. What people were not factoring into their research was that plant health and growth are determined by the interaction of many factors that cannot be realistically considered in isolation."

The goal of the ROPIS program is to develop general theories and models that apply in Kansas or California, whether the plant of interest is wheat or pine trees, and whether the threats facing a plant are natural or man-made. "The ROPIS project is a very important part of EPRI's efforts to assess the effect of utility operations on ecosystems," says Dr. John W. Huckabee, EPRI program manager for ecological studies. "ROPIS will provide a framework

The Range of Research

Forests, agricultural experiment stations, and university laboratories are the five-year field research sites where EPRI-sponsored investigators are monitoring environmental variables and measuring concurrent changes in tree growth, health, color, vigor, and so on. The nationwide range of subjects includes red spruce, sugar maple, ponderosa and loblolly pine, cottonwood—and radishes, chosen in part because they grow and register change rapidly. Open forests represent natural settings, but partially enclosed chambers are a necessary compromise for controlling such stress factors as acid deposition exposure and ozone level.

that for the first time quantitatively links the amount of deposition with specific effects on vegetation."

Phase 1 of the project is scheduled to be completed in 1992 at an estimated cost of $13 million. Now at the halfway mark, this phase has already produced some important results. Three conceptual mathematical models have been developed to provide computer simulations of how plants grow in response to changing environmental or climatic conditions. The manmade stresses considered to date include acid precipitation, ozone, and sulfur dioxide. Doses are at levels lower than, the same as, and greater than ambient levels in the United States today.

Although the work done so far is clearly not sufficient to give a full picture of how plants react to stresses, some preliminary conclusions can be made on the basis of the one to two years of experimentation now complete. Studies of seedlings and saplings have shown no decreases in growth or vitality from exposure to acid precipitation and no adverse effects of ozone in combination with acid rain that exceed those of ozone alone. Negative growth responses to ozone have been observed.

Generally, the research has found that there is a tremendous range of stress responses both between and within species, and that reactions to a single stress vary tremendously, depending on what other stresses are present. In addition, there are major differences in a plant's response to the same pollutant from year to year, depending on changes in other environmental conditions. An encouraging finding is that plants can compensate for stresses quite a bit by altering their distribution of resources to maintain growth, putting more energy into certain areas to make up for injuries.

These and other specific findings will continue to be incorporated into the mathematical models that have been developed to simulate plant responses to interacting stresses. These models, which predict how vegetation would respond to hypothetical air pollution or climate modification scenarios, will be verified and tested over the remainder of phase 1. "Based on the evidence today, there would not seem to be any major long-term implications regarding plant injuries caused by acid precipitation, but this study is too short to draw any definitive conclusions," Goldstein says. "When our computerized models are complete, we'll be able to make the necessary long-term predictions."

Regional results

Although a key study objective is to develop models that apply to all stresses and all vegetation, ROPIS is also providing valuable information about specific pollutants and species. The study is organized in four modules: East, South, West, and Basic Mechanisms. The first experimental seasons of fieldwork for the East and South modules were in 1987; work under the West and Basic Mechanisms modules began in 1988. Each of the four program modules has produced important results in areas of immediate regional concern.

The ROPIS East module, under the direction of investigators at the Boyce Thompson Institute for Plant Research and Cornell University, is studying the effects of acid precipitation and ozone on red spruce and sugar maple trees. The Empire State Electric Energy Research Corp. (ESEERCO), a not-for-profit research corporation funded by the seven major electric systems in New York state, and Niagara Mohawk Power are cofunding the research.

"After two years of exposure, we have not seen any statistically significant effects of either ozone or acid rain on photosynthesis," according to Dr. Robert Kohut, a plant pathologist at Boyce Thompson and a principal investigator for ROPIS East. "The first thing you would expect to see is some change in photosynthesis, which would then be reflected in a growth reduction." However, trees that received the most acidic treatment have been slower to develop cold tolerance in the fall. Although these trees eventually reach the same level of cold tolerance as other trees, they might be more prone to injury if an extremely cold period occurred in the fall, hypothesizes Kohut.

In addition, findings indicate that the most acidic treatment is removing some nutrients from the tree foliage, although no nutrient deficiencies have appeared. Kohut cautions that for long-lived organisms like trees, however, effects may not occur until after several years of exposure.

The ROPIS South module, under the direction of investigators at the Tennessee Valley Authority and Oak Ridge National Laboratory, is studying the effects of acid precipitation, ozone, and soil magnesium levels on loblolly pine seedlings. TVA is cofunding the research.

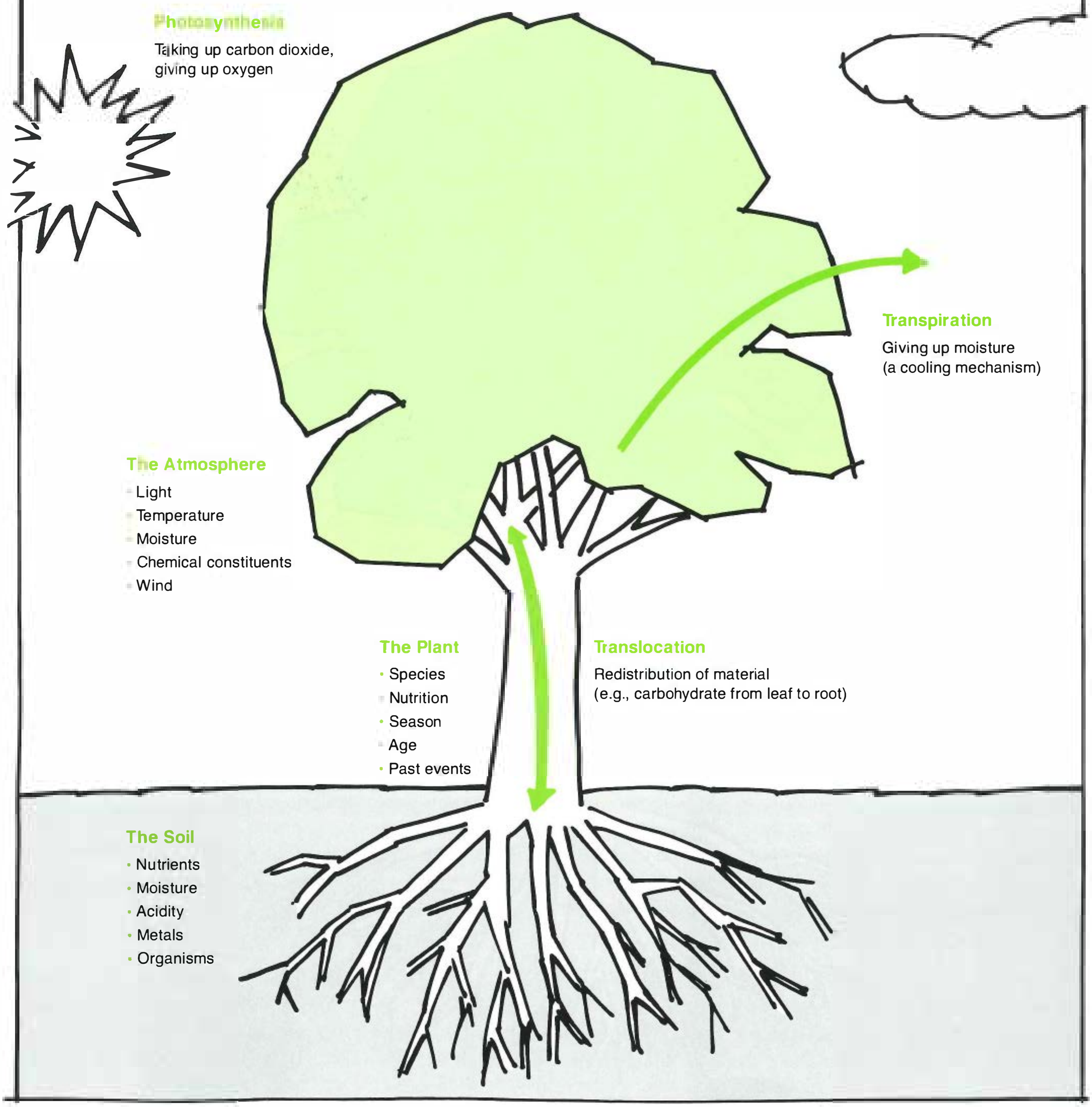
After two years of field study, Dr. J. Michael Kelly, project manager for the cooperative forest studies program at TVA and a principal investigator for ROPIS South, reports that he has seen no significant acid rain or magnesium impacts and no synergistic impacts of the combined effects of ozone, acid rain, and magnesium that are greater than the individual impacts. "We're basically seeing an ozone impact," Kelly says. The study has found that ozone reduces the trees' ability to store carbon, which is the principal building block of the plant, and that this reduction affects plant growth.

Although the ozone treatments have not reduced nutrient uptake as much as anticipated, the investigators have also observed a significant reduction in root growth, or a lower root-shoot ratio, in the ozone-treated trees. In addition, ozone may be altering the microbial relationships that affect the trees' ability to take up nutrients from the soil. These important relationships between plant roots and mycorrhizae, a group of soil fungi, increase the absorptive area of the root system. Pines are particularly dependent on these relationships, which allow them to extract more nutrients from infertile soil.

In spite of these negative ozone im-

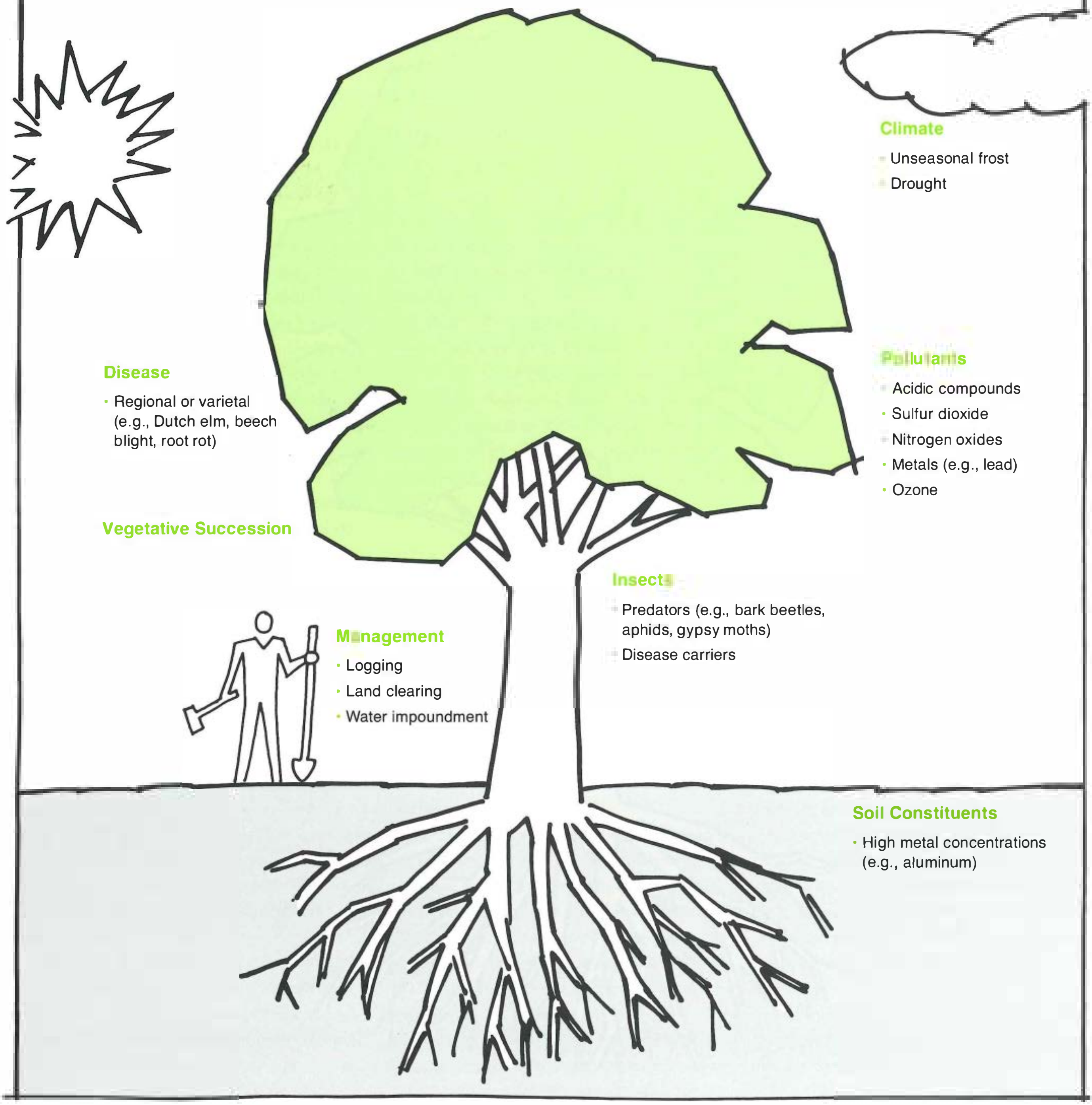
What Makes a Forest Grow

The life of a tree isn't all sunshine and rain. Just as with people, such factors as genetics, nutrition, and care (or its absence) play a part. And they interact in both known and unknown ways. Research data and analyses are yielding an understanding of process mechanisms that can be computer-modeled to represent behavior under normal growing conditions.



What Stresses a Forest Community

Trees and other vegetation are subject to cyclic and random processes, most of them natural but others directly or indirectly triggered by human activity. The mechanisms and effects of stress may be immediate and obvious, or they may be subtle and drawn out, such as the gradual change in plant species that we call vegetative succession.



pacts, Kelly observes, the experimental trees compensated successfully for such stresses. Plants treated with higher-than-ambient levels of ozone during the growing season (April to September) made a significant recovery in winter, when the ozone stress was removed. "By playing catch-up during periods of semidormancy—during winter in such warmer locales as Tennessee—plants compensated for the ozone-induced growth loss," Kelly says. "By the beginning of the next growing season, all our experimental plants had reached essentially the same level."

The ROPIS South experiment also uncovered major differences among genetic strains of loblolly pine in terms of their sensitivity to ozone. "At the current levels of ozone ambient in the Southeast, some trees in any given population will respond and others will not," Kelly says. "If a particular family is ozone-sensitive, you can avoid those trees in a commercial planting."

The ROPIS West module, under the direction of investigators at the University of California (Riverside and Berkeley) and the U.S. Forest Service, is examining the effects of acid precipitation, ozone, and drought on ponderosa pine. Southern California Edison, the Forest Service, and the National Council of the Paper Industry for Air and Stream Improvement (NCASI) are all supporting the effort.

During the first year, we found the most significant influence on tree growth was drought," says Patrick Temple, the UC-Riverside botanist who is a principal investigator for ROPIS West. "Acid deposition had no effect in the first year in either its wet or dry form. Ozone also had no effect on tree growth, but we did see visual ozone injury symptoms—a mottled yellowing of the needles—indicating that in future years ozone may affect growth." The ROPIS West results also suggest that drought can significantly alter the response of trees to pollutants. During a drought, injury from ozone exposure may be notably reduced. But immediately following a drought, ozone exposure may very severely reduce tree growth.

Temple cautions that the ROPIS West results are extremely preliminary, since only one of three scheduled field seasons is complete. Moreover, ponderosa pines take 50 years to mature and can live for over 600 years. "We're not growing tomatoes or bean plants," Temple says. "Our entire experiment may not continue long enough to see significant changes from these pollutant treatments."

The Basic Mechanisms module, under the direction of investigators at Stanford, Oregon State, Pennsylvania State, and Texas A&M universities, is studying the effects of ozone, sulfur dioxide, nutrient, and water stresses on radishes and cottonwood. Both field and laboratory work are being pursued to uncover general principles governing plant response to stresses.

"Plants almost never grow in an optimal environment—there's always something limiting their growth," says Dr. William E. Winner, associate professor of biology at Oregon State University and a principal investigator in the Basic Mechanisms module. Two seasons of radish studies are complete, with one more under way. Fieldwork with the cottonwood begins next year and will continue through 1991.

"Our radish studies have shown that ozone levels typical in the eastern United States today during summer months can significantly affect radish growth, development, and physiology," Winner says. "Radishes compensate for ozone stress to maximize their growth, but growth reductions occur nonetheless. In addition, compensation for ozone stress can reduce the plant's ability to compensate for decreasing nutrient supplies."

Such an observation points up the complicated trade-offs built into plants' compensation mechanisms. For example, a shift in carbon partitioning within the leaf, a change in the leaf area-weight ratio, or a change in the root-shoot ratio will allow a plant to maximize growth in the face of stress. "By understanding compensation mechanisms, we can create a hypothetical framework to help predict how plants might respond to future stresses," Winner says. "The remarkable resilience plants show to environmental stress is something of a surprise, as is the wide array of ways they have to cope with stress."The key question Winner hopes to answer over the remainder of the study is whether the general principles seen with the radish can be extended to more complex growth forms, such as the cottonwood.

Interested parties

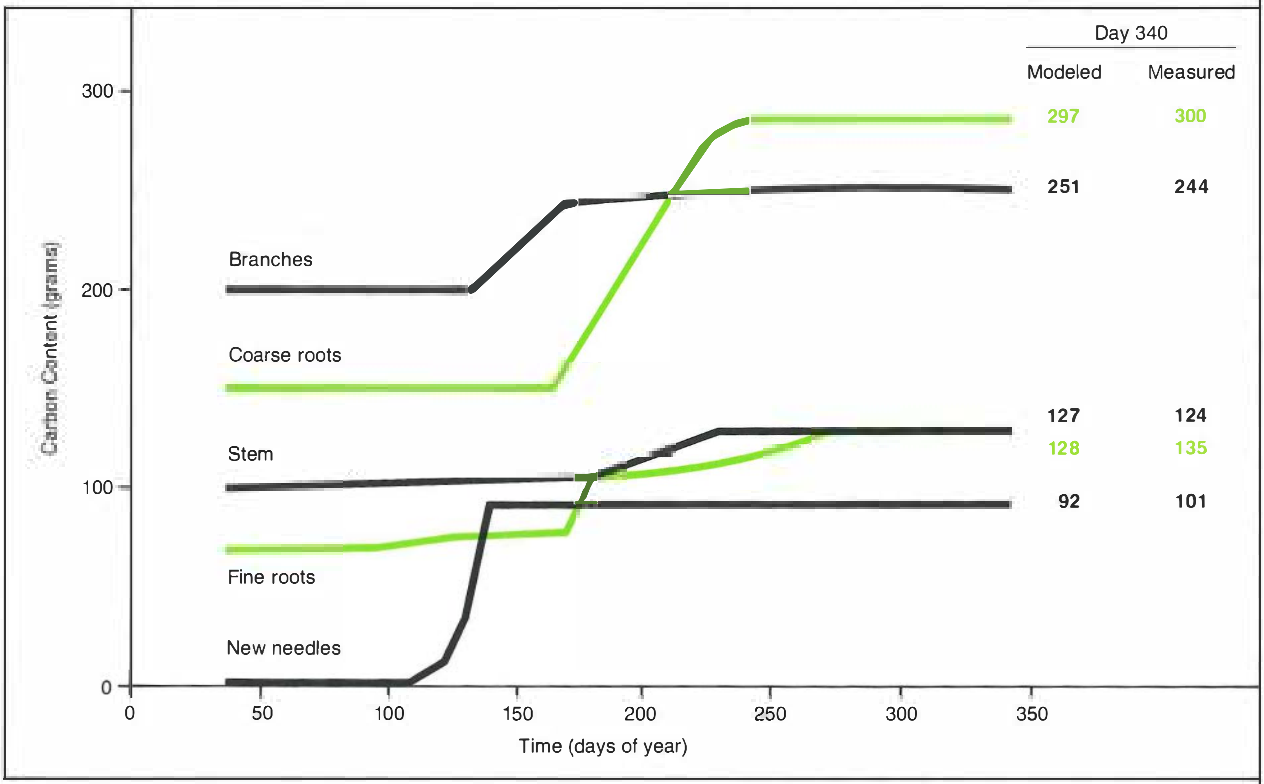
The significance of ROPIS extends far beyond EPRI itself to the government, EPRI's member utilities, the forest products industry, and academia. "As a regulator, government is burdened with the task of writing regulations on the basis of quantitative linkage of emissions and effect," EPRI's John Huckabee says. "At the present time, adequate tools to do this simply are not available."

Dr. Patricia M. Irving, associate director of the National Acid Precipitation Assessment Program (NAPAP), the agency that coordinates all federal acid precipitation research, confirms that ROPIS fills a major gap in providing information on terrestrial processes not available from federally funded programs. "NAPAP intends to use the ROPIS models to obtain information on what would happen to forest conditions under various emission reduction scenarios," Irving says. "The data will be included in NAPAP's final assessment for the President and Congress to guide policymakers in setting federal standards for major pollutants contributing to acid rain."

NAPAP will also use the models and scientific information from ROPIS in a series of "state of the science and technology" reports to be issued later this year. These technical reports will provide the foundation for lay summaries directed to the policymakers responsible for formulating new clean air regulations.

The Picture of Forest Health

Cornell researchers can now predict the normal development of a species such as red spruce over the period of a year after its measurements at day 40 (early February). A newly developed computer model projects changes in carbon content, at quite different rates throughout the tree structure, and yields final values at day 340 that are not too different from those measured in the tree itself.



Since electric utilities and forest products companies face the possibility of dozens of costly new environmental restrictions, both groups have a major interest in establishing what the effects of man-made pollutants really are. Therefore, these industries have been actively cofunding the ROPIS program. "EPRI's philosophy is that we don't merely transfer the results of our research to industry at the end of a study," Goldstein says. "We try to involve the industry up front, in many cases getting them to cofund, so that when the final product is produced, they know how they're going to use it, because they've been working with us from day one."

ROPIS is so important to ESEERCO members that they are paying an additional assessment beyond their EPRI dues to support the study. ESEERCO's specific concerns center on an alleged decline in sugar maple tree growth and maple syrup production that is being blamed on acid rain. "Our pollution control law in New York is flexible, based on the effects of acid deposition shown to occur," says Kevin T. McLoughlin, ESEERCO's administrator for land use and industrial waste programs. "The results of the ROPIS study will be submitted to the New York State Department of Environmental Conservation."

In Tennessee, local concerns center on whether the loblolly pine is showing any growth reduction due to ambient ozone or acid precipitation levels. The U.S. Forest Service has observed a decline in growth rates in pines of the Southeast, which some have associated with drought, acid rain, or ozone. TVA, the federal agency charged with producing power, managing resources, and promoting economic development in the Tennessee Valley region, wants to know to what degree, if any, its power plant emissions are contributing to the decline of pine trees, which are economically important throughout the region. "Our goal is to have the ROPIS information impact the final NAPAP assessment," says Patricia F. Brewer, a TVA research biologist.

Beyond the specific concerns of utility cosponsors, ROPIS results will have general value for the industry at large by clarifying issues and helping companies communicate better with federal and state agencies. "The ROPIS program will provide data to help utilities work with regulators to provide reasonable solutions to clean air issues," Goldstein says. "Our program facilitates working with government in a nonadversarial manner."

The ROPIS study has a similar value for the forest products industry, which is why NCASI decided to join ROPIS as a cofunder. NCASI, the environmental studies arm of the pulp and paper industry, is supported by member companies representing more than 90% of the paper production capacity in the United States.

"Our industry depends on trees as a source of raw materials, so any possible threat to forests is taken very seriously," Dr. Alan A. Lucier, a research forester with NCASI, says. "On the other hand, we are also a major user and producer of energy, and we believe that any additional regulations on air emissions should be carefully designed to provide demonstrated benefits to forest health and other environmental values.

"The number one concern of the NCASI forest health program is to determine whether there really is a problem with air quality and forest health," Lucier says. "Because of the long-lived nature of trees and the relatively low levels of pollutants we're concerned with, any effects will be subtle and only manifested over a period of several years or more. Long-term studies like ROPIS will be the most important in determining whether there are these subtle effects."

Dr. David F. Grigal, professor of soil science and forestry at the University of Minnesota in St. Paul and a member of the ROPIS advisory committee, confirms the importance of long-term research in studying forest conditions. Most academic research is of much shorter duration, according to Grigal. "The ROPIS study is unique in that so many resources and such a large number of talented people have been brought together for so long a period," he says. "Trees may take a couple of years of treatment to reach a stable response to the stresses being tested; as the study progresses, we will get more and more realistic results."

Looking ahead

While phase 1 of ROPIS is emphasizing acid deposition and ozone as the man-made stresses of concern, phase 2 will study other atmospheric pollutants, including nitrogen dioxide, and will even consider global climate modification—the greenhouse effect—in conjunction with EPRI's ecological research on greenhouse gases. "Although we began our work with the stresses that were an issue in the mid-1980s, we now have tools on the shelf to deal with whatever stress comes along," Goldstein says.

TVA's Kelly adds that the development of a ROPIS model sufficiently robust to address many different situations is "the real payoff of the ROPIS project and one of the major values to the utility industry." By allowing the utility industry to run "what if" scenarios to answer such questions as whether adding nutrients to the soil will offset an impact, the ROPIS model becomes a very powerful tool.

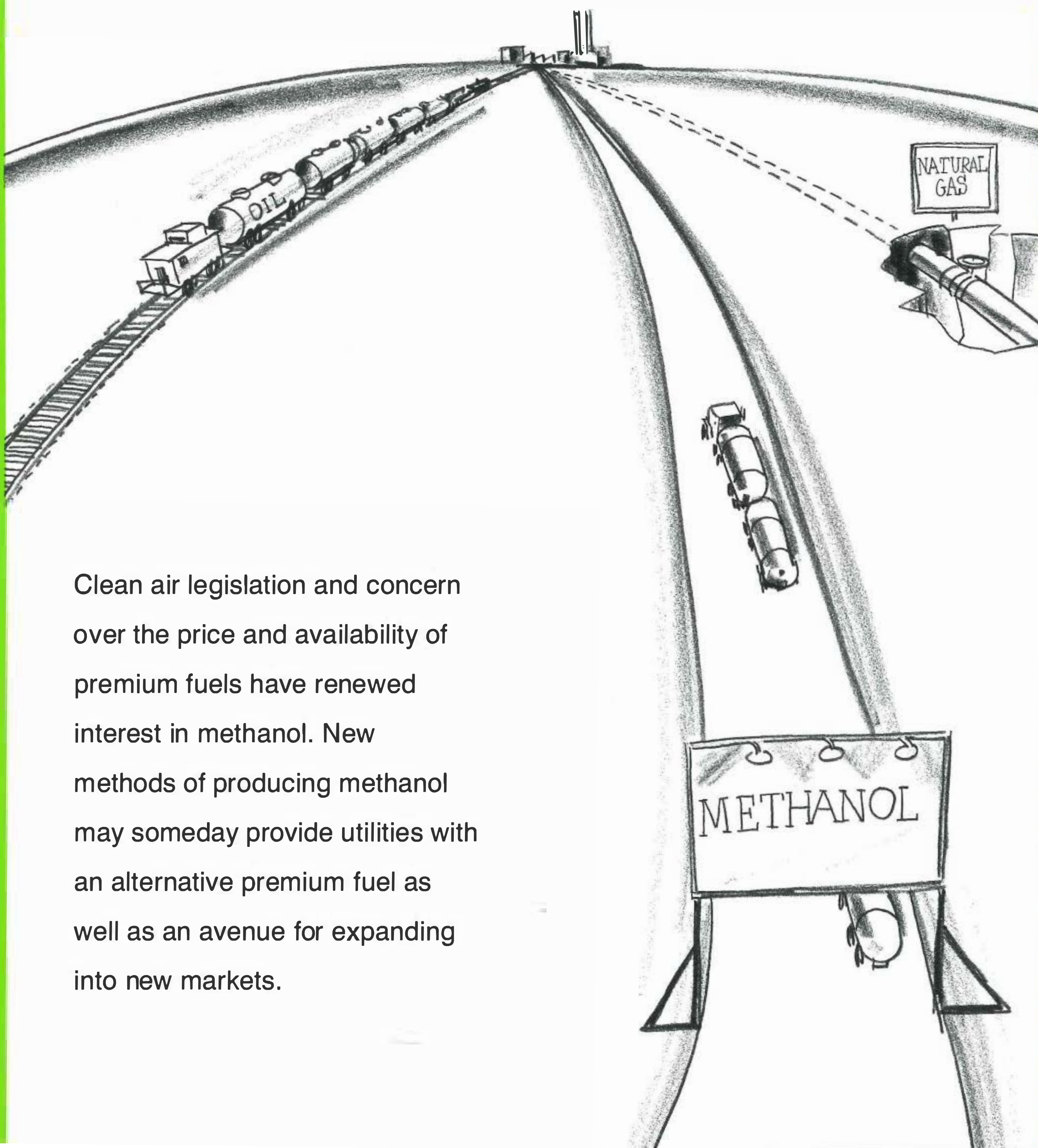
The second phase of the ROPIS program also will focus on increasing the generality of the computerized models and testing their veracity. When complete, the models will allow users to make reliable projections for decades in the future. "Since we can't realistically do experiments for 20 years, these refined models will provide an invaluable tool," Goldstein says.

David Grigal echoes Goldstein's sentiments. "If ROPIS succeeds, we'll have a way to understand the 'stress a day' crises without funding a major new research project each time." ■

This article was written by Peggy Waldman, science writer. Background information was supplied by Robert Goldstein, Environment Division.

Methanol

A Fuel for the Future?



Clean air legislation and concern over the price and availability of premium fuels have renewed interest in methanol. New methods of producing methanol may someday provide utilities with an alternative premium fuel as well as an avenue for expanding into new markets.

A dozen years ago, when oil embargoes forced Americans to endure long waits at the gas pump and the executive branch proclaimed energy independence as a new national goal, methanol enjoyed a fleeting period of popularity. It was championed by conservationists as a clean-burning alternative fuel for motor vehicles and utility combustion turbines, and it was seen as a hedge against uncertain supplies of foreign oil, since it could be provided from plentiful domestic supplies of natural gas or coal. But as the price and availability of oil stabilized in the 1980s, energy independence dropped down the list of priorities. Methanol didn't capture the interest of automakers or utilities, who were reluctant to commit to a new fuel that was limited in supply and higher in price than oil or gas. Having failed to penetrate the fuel market, methanol remained a chemical feedstock for higher-value hydrocarbons.

But the situation may change in the future. Methanol synthesis technology has improved substantially in recent years, promising lower costs. And clean air legislation proposed by the Bush administration strongly favors the production and use of alternative fuels—with methanol among the most-favored contenders. If the proposals are implemented, they could open a huge new market for the alcohol fuel. In addition, improved synthesis methods may be used to convert the methane in natural gas into methanol, allowing untapped gas reserves in remote regions to be brought to market in liquid form without relying on costly cryogenic technology. Ultimately, as the price of natural gas feedstock increases, methanol will be made by gasification of coal from the United States' vast reserves, and may also be used to replace petroleum-based transport fuels.

EPRI's Fuel Science Program has sponsored methanol research since the mid-1970s—most recently, in collaboration with the Office of Exploratory Research. Initially spurred by the national drive for energy independence, the work has continued with the purpose of providing utilities greater flexibility in generating power by expanding their choice of low-cost fuels. The program aims to raise the efficiency and lower the cost of producing methanol, and to make it more useful to electric utilities—both as a new fuel option for the growing number of combustion turbines coming on-line and as a salable by-product of power generation. Projects range from work on the threshold of commercial application to ambitious exploratory research that promises a significant, if distant, payoff. In LaPorte, Texas, an advanced process for making methanol from coal-derived gas is being scaled up to the commercial demonstration stage. EPRI-supported research at Brookhaven National Laboratory has resulted in the development and bench-scale testing of a novel catalyst that produces methanol at low temperatures and pressures, with much simpler technology than that used in conventional systems. And in a significant scientific achievement, a researcher at Lawrence Berkeley Laboratory has produced synthetic catalysts that mimic the action of natural enzymes that convert methane directly to methanol—performing at room temperature what chemical plants do in complicated, multistep procedures using high temperatures and pressures.

"Improved methanol synthesis technology provides a path for taking an abundant feedstock, methane gas, and converting it to a liquid fuel that can be readily stored, transported, and burned in combustion turbines," says Conrad Kulik, project manager for process development in the Fuel Science Program. Ease of storage and transport is a significant concern, as utilities turn increasingly to combustion turbines to meet the peaking and intermediate load growth projected for the next decade. Bringing in natural gas to feed those turbines may not always be easy or cheap. Plans to extend gas lines often encounter public opposition, and many utilities may prefer to use a liquid fuel that can be delivered by road or rail. With the leading liquid turbine fuel, petroleum distillate, subject to uncertainties in price and supply, methanol may prove a practical and cost-effective option.

"Ease of transport and storage is certainly a major advantage," says Kulik. "Working with a liquid is an order of magnitude easier than working with a gas, especially for utilities that use it as a fuel for combustion turbines providing a few hours of peak power per day."

There are trade-offs between methanol and other combustion turbine fuels, Kulik notes. "Methanol has a lower Btu value per unit volume than fuel oil, and it's less of a carefree fuel—it's volatile, so it's important to eliminate leaks that could release vapors, as well as potential ignition sources." Such precautions would also apply to natural gas, however, and to other chemicals used in utility operations. Although methanol enjoys a reputation as an inherently clean fuel because it emits low levels of hydrocarbons, particulates, and oxides of nitrogen, it does produce some undesirable combustion products, chiefly formaldehyde. This drawback may be amenable to engineering solutions, according to Kulik. For example, it may be possible to reduce the formaldehyde emissions by using a catalytic combustion system or other emission reduction technologies.

"Methanol has potentially two very different roles for electric utilities," says Howard Lebowitz, manager of the Fuel Science Program. "In the near future, the conversion of remote natural gas to methanol is a way to bring more natural gas to market than would be possible with the existing infrastructure. In the longer run, utilities will replace natural gas with coal-derived gas produced in gasification–combined-cycle power plants. At that time, it will be advantageous for utilities to become methanol producers. The conversion of gas to methanol in a gasification power plant will improve the utilization of the plant and provide clean fuel to use in other power plants."

Producing methanol along with electricity not only provides clean fuel but also represents a new business opportunity for utilities facing an uncertain future, emphasizes Michael Gluckman, technical director of the Engineering and Economic Evaluations Program. "As the electric power industry prepares for the 21st century, it faces unprecedented challenges," says Gluckman. "Competition, environmental issues, uncertainties in the supply and availability of premium fuels, and a rapidly changing regulatory environment—all of these factors are changing the business of generating electric power and are making the industry's future difficult to predict. However, these challenges also create potentially profitable opportunities for companies willing to adapt to the new business climate."

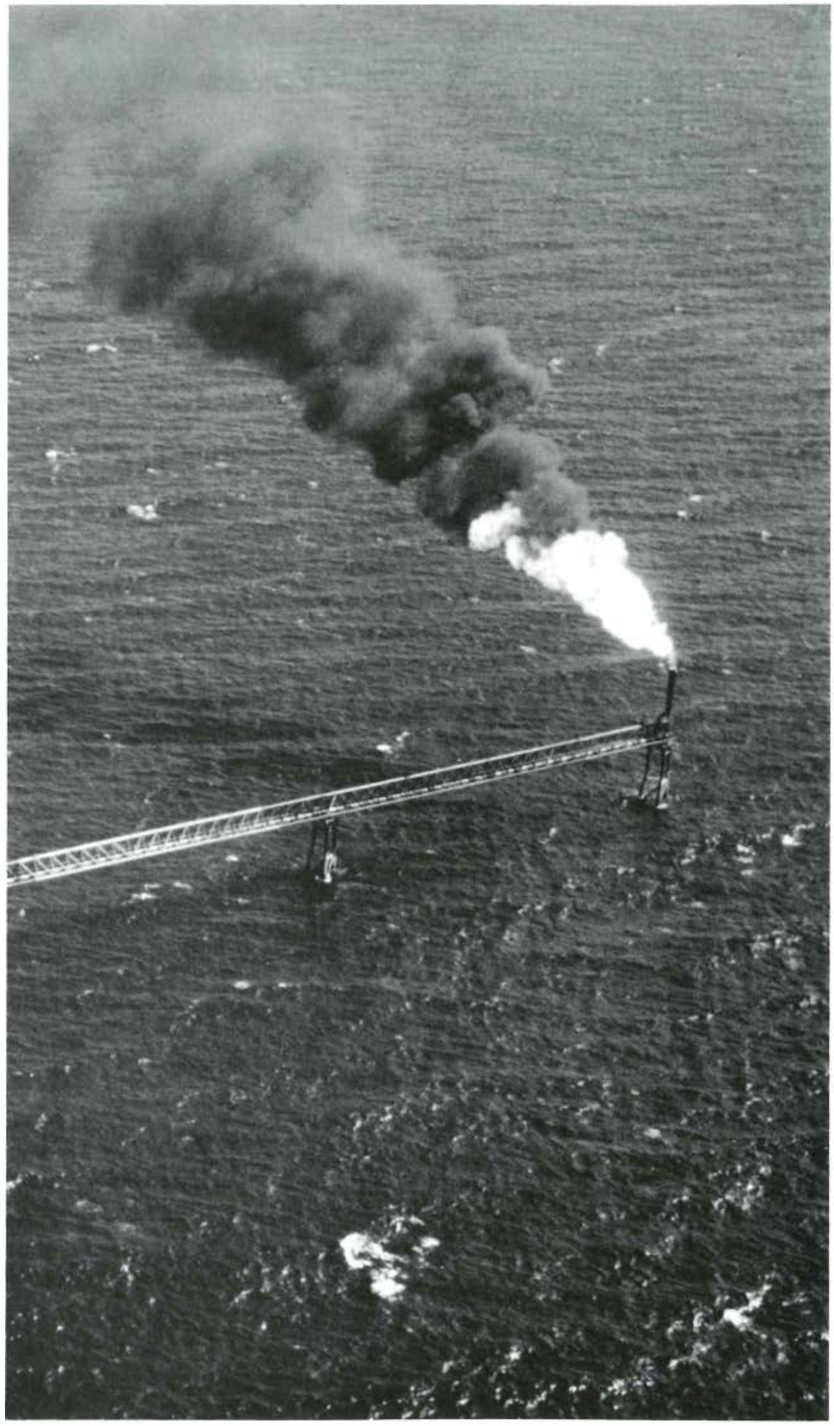
To remain competitive in the future, Gluckman says, utilities must maximize the value added to both their invested capital and purchased fuel. One way of doing this, he explains, is to become more process oriented, converting feedstock not only to electricity but also to methanol and other chemical products. "This type of diversification increases the value added to capital equipment and fuel," says Gluckman. "It also provides a long-term opportunity for reduced revenue requirements that will significantly improve the utility industry's competitiveness."

Making methanol

Methanol is a versatile commodity widely used in the chemical industry as a raw material for a broad range of hydrocarbon products, including formaldehyde, plastics, methyl *t*-butyl ether (MTBE, an octane booster added to gasoline), and gasoline itself. New Zealand, which has to import much of its petroleum, operates a commercial plant that converts methane to methanol, then coverts the methanol to gasoline with technology developed by Mobil Corp.

The Transportation Factor

Large reserves of natural gas exist in remote areas that are not served by pipelines. Because it cannot be brought to market economically, the gas is often flared and wasted. Converting the methane in remote natural gas to methanol, an easily stored and transported liquid, could open this abundant and untapped energy supply and facilitate bringing it to the point of use.



In today's commercial processes, methane (CH_4) is converted to methanol (CH_3OH) in a two-step procedure. The methane is first reacted with water and heat to produce a synthesis gas consisting of carbon monoxide and hydrogen ($CH_4 + H_2O \rightarrow CO + 3H_2$). This step is called steam reforming. In the second step, the synthesis gas is converted to methanol, using a copper-based catalyst to promote the reaction ($CO + 2H_2 \rightarrow CH_3OH$). While this may seem simple enough, both steps of the process carry built-in obstacles that exact penalties in the form of energy loss and cost.

The first obstacle is the tenacity of the methane molecule itself. Methane is a tough nut to crack. Its simple structure—four hydrogen atoms arranged symmetrically around a single carbon—makes it extremely unreactive except at high temperatures and pressures. Its carbon-hydrogen bonds are among the strongest and most stable found in the hydrocarbons, requiring 104 kilocalories/mole to break, and the molecule's tetrahedral shape provides no avenue for chemical attack. Since a lot of energy is required to break apart, or activate, the methane to form the synthesis gas, the reforming step is both thermodynamically inefficient and costly.

Converting the synthesis gas to methanol presents another obstacle that has served to keep methanol more expensive than competing fuels. The reaction is highly exothermic—a lot of energy is released as heat when the carbon monoxide and hydrogen combine to form methanol. This presents a design challenge because the zinc-copper catalyst is sensitive to temperature; it requires 250°C to do its job, and higher temperatures will either deactivate it or shorten its life. While it's desirable to run the conversion rapidly to produce a lot of methanol quickly, the faster the reaction proceeds the more heat is generated, potentially leading to catalyst deactivation. To obtain a good yield while preserving the catalyst, therefore, the reaction heat must be removed while maintaining close temperature control in the reaction chamber.

In addition to being sensitive to temperature, the catalyst is susceptible to poisoning—deactivation from contact with such trace impurities as carbonyls, sulfur, and cyanide compounds. Hence the synthesis gas must be purified before it enters the reactor. Sustaining catalyst life and improving reactor productivity are key thrusts of the efforts to boost the efficiency and economics of the two-step conversion process. The challenge is to maintain an environment in which the catalyst can operate over extended periods with good selectivity—producing the desired compound—at a high rate of conversion.

Today's commercial methanol production technology is dominated by two processes, one developed by Lurgi and one by Imperial Chemical Industries (ICI), which convert synthesis gas to methanol in gas-phase reactors using a zinc-copper catalyst. Removing the heat unleashed by the exothermic reaction is accomplished either by injecting cool, unreacted gas into the reaction chamber or by providing internal cooling surfaces. These reactors operate on a diet of diluted synthesis gas hydrogen is added to slow down the reaction and control the buildup of heat. To obtain the desired yield, the gas has to be recycled through the reactor many times.

Liquid-phase methanol

EPRI has partially funded the development of an advanced process for making methanol from synthesis gas that promises to reduce the cost of methanol production and whose operation is more suited to the needs of the utility industry. The process differs from gas-phase systems in that the catalyst is suspended in an inert hydrocarbon liquid, such as mineral oil, which adsorbs the heat of the reaction much more effectively than gas. The liquid-phase methanol reactor, developed in the mid-1970s by Chem Systems, offers several advantages over conventional methanol reactors. Perhaps of most significance to utilities, it can use synthesis gas derived from the gasification of coal, which has a higher proportion of carbon monoxide than the syngas used by gas-phase reactors. This results in a higher conversion per pass and reduces the need for recycling, with its associated energy penalty. In addition, the design permits operators to replace a fraction of the spent catalyst with a fresh batch rather than shutting down the reactor to replace the entire catalyst inventory.

The liquid-phase methanol process has been extensively tested during the course of an eight-year project conducted at the synthesis gas–generating facility of Air Products & Chemicals in LaPorte, Texas. Tests conducted with a process development unit (PDU) have successfully demonstrated the technology at a representative engineering scale and have provided the experience needed for fine-tuning the system to improve its economics.

During a four-month test run conducted last fall and winter, the unit produced methanol from simulated coal gas, achieving yields as high as 12 tons of methanol per day. The purity of the methanol has consistently exceeded 96%, making it well suited for use as fuel. Plans are now under way to bring the technology to the commercial demonstration stage, with the goal being a unit that operates on real coal gas and produces methanol at the rate of 500 tons per day.

The liquid-phase technology's success in converting unbalanced gas to methanol has led to the development of a scheme that could help utilities improve their operating flexibility in the future. The liquid-phase methanol reactor can be coupled to an integrated gasification–combined-cycle (IGCC) power plant, allowing utilities to coproduce methanol and electricity. IGCC plants react coal with oxygen and steam to produce synthesis gas, which is then stripped of sulfur and other impurities and burned in combustion turbines. In a process called once-through methanol, or OTM, the cleaned synthesis gas passes through a liquid-phase methanol reactor, which converts about 20% of the energy in the gas to methanol; the methanol is recovered and stored, while the remaining gas proceeds to the combustion turbine. The stored methanol can be burned in turbines performing load-following and peaking duty, or it can be sold as a commodity to outside markets.

EPRI-sponsored studies have shown that the once-through methanol process may increase the economic appeal and flexibility of an IGCC plant. Storing methanol produced during offpeak hours allows the gasification system to be sized for average rather than maximum load, because additional fuel requirements could be met by the stored methanol. Since the gasification system accounts for about half the capital cost of an IGCC plant, the addition of an OTM unit could result in an overall capital cost reduction of almost 10%.

EPRI-sponsored research at the University of Akron has produced a spin-off of the liquid-phase methanol technology that is significant from a scientific as well as a commercial perspective. Researchers at the university have been supporting the project through a range of experiments that seek to improve our basic understanding of methanol synthesis chemistry and of the factors that determine the durability and longevity of catalysts. The researchers found that as newly formed methanol accumulated in the reactor, it began to inhibit the production of additional methanol as the reaction approached equilibrium. Some means of removing the methanol, or converting it to another chemical species, was needed to lower methanol concentrations in the reactor. In their pursuit of a solution to the problem, the researchers found that by adding a second catalyst, it was possible to produce dimethyl ether (DME) efficiently along with methanol. This dual-catalysis approach has not been successfully used before. EPRI has filed a patent application for this DME-methanol coproduction process.

The ability to make DME along with methanol may prove to be a significant side benefit of the liquid-phase technology, EPRI's Kulik says, and could provide an avenue for utilities to expand into a new market. European aerosol manufacturers are turning to DME as a replacement for the chlorofluorocarbons (CFCs) used as aerosol-spray propellents. Concern over the role of CFCs in contributing to the destruction of stratospheric ozone has led to an international agreement (the Montreal Protocol) calling for sharp reductions in CFC use. Although the United States phased out CFCs in aerosols in 1978, other nations are just now doing so, and a highly competitive market has emerged for ozone-friendly CFC substitutes.

A power plant that could produce electricity as well as methanol and DME for sale to outside markets would represent a step toward an integrated energy facility, according to Gluckman. In such a facility, coal would be gasified to produce synthesis gas at a baseload capacity factor of 90%. This gas would feed combined cycles or fuel cells operating at lower capacity factors than the gasification plant. When the synthesis gas wasn't being used for power generation, it would be diverted to chemical production units to make a variety of chemical products and fuels. Coproducing electricity and chemical products in a fully integrated energy facility could potentially reduce the cost of generating electricity by approximately 40%, while minimizing air emissions and solid-waste production. And because of the facility's high efficiency, carbon dioxide production per unit of energy produced would be significantly lower than at any coal-burning plant generating electricity only.

Pursuing a cooler path

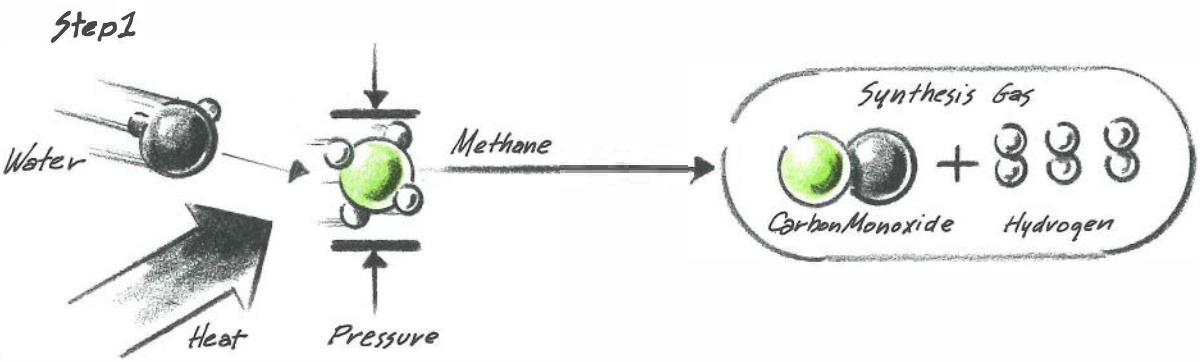
Meanwhile, a different project is developing a methanol process that promises to overcome the temperature limitations of conventional methanol catalysts. Researchers at Brookhaven National Laboratory are testing a novel low-temperature, low-pressure catalyst that can convert synthesis gas to methanol with a conversion rate greater than 90% in a single pass. While the project remains at the bench-scale stage, it has demonstrated considerable potential for practical application, and negotiations are in progress for a pilot-scale demonstration.

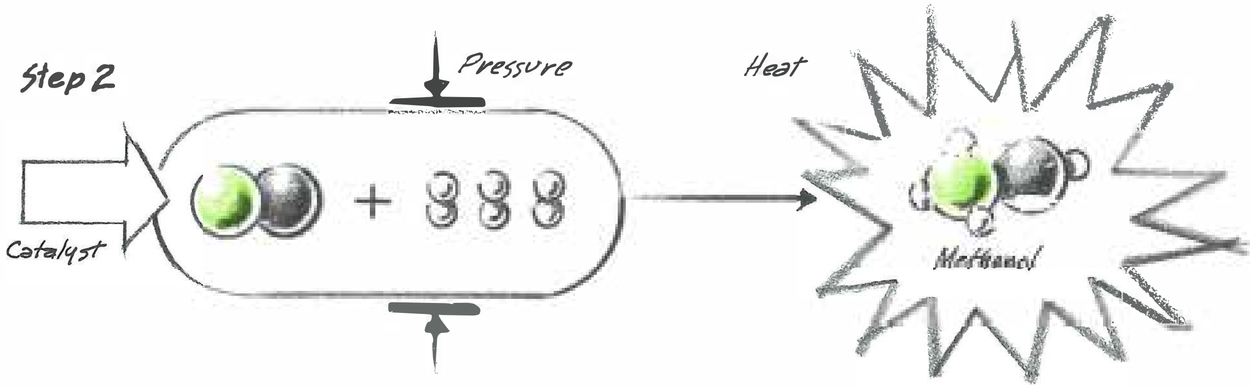
The liquid-phase catalyst, called FAST-M, operates at 100°C and 100 psi, in comparison to the 250°C and 750 psi required by the conventional copper-zinc catalysts. This is significant for two reasons. The conversion to methanol ($CO + 2H_2 \rightarrow CH_3OH$) is favored at low temperatures, so FAST M allows a much higher conversion rate per pass and eliminates the need for costly recycling of unconverted gas through the reactor. Since high temperatures and pressures aren't required to keep the catalyst alive and working, a plant using the FAST-M catalyst could be relatively simple. In addition, the catalyst has a tolerance for common methanol catalyst poisons, which reduces the need for and expense of cleaning the synthesis gas. FAST-M's low-pressure operation may allow the use of synthesis gas made from air rather than pure oxygen. With today's methanol catalyst, in contrast, the nitrogen diluent from the air would require very high pressure in order to achieve reasonable methanol conversions. The FAST-M catalyst can also work with coal-derived gas and may in the future be incorporated into a once-through process.

The Brookhaven process may also prove to be appropriate technology for converting remote natural gas to methanol for transportation and storage. Natural gas is a difficult commodity to transport; it must flow through pipelines or else be shipped as a cryogenically chilled liquid. Quantities of natural gas, perhaps as much as two-thirds of the world's resources, are located in remote areas that lack the storage and delivery systems needed to bring that gas to market. If this remote gas could be efficiently converted to methanol, it would be far cheaper and safer to store and transport.

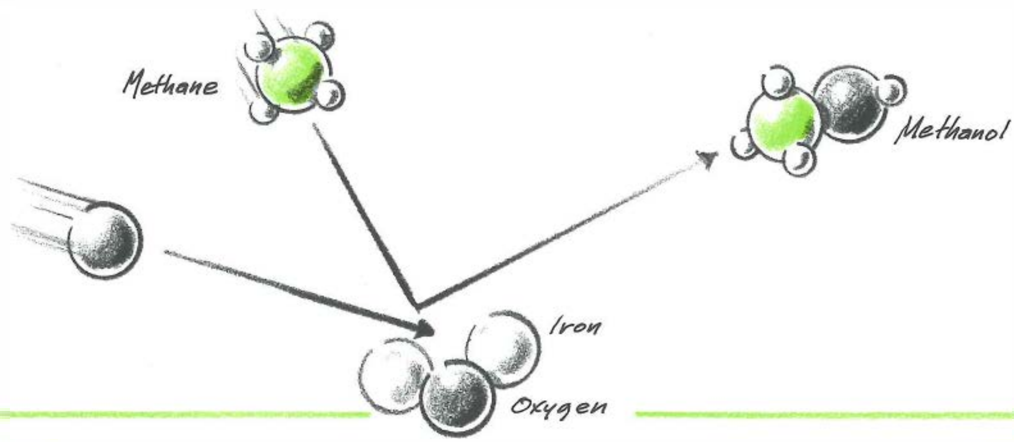
Methane to Methanol

Making methanol from methane with today's technology generally involves a two-step process. The methane is first reacted with water and heat to form carbon monoxide and hydrogen—together called synthesis gas. The synthesis gas is then catalytically converted to methanol. The second reaction unleashes a lot of heat, which must be removed from the reactor to preserve the activity of the temperature-sensitive catalyst. Efforts to improve methanol synthesis technology focus on sustaining catalyst life and increasing reactor productivity.



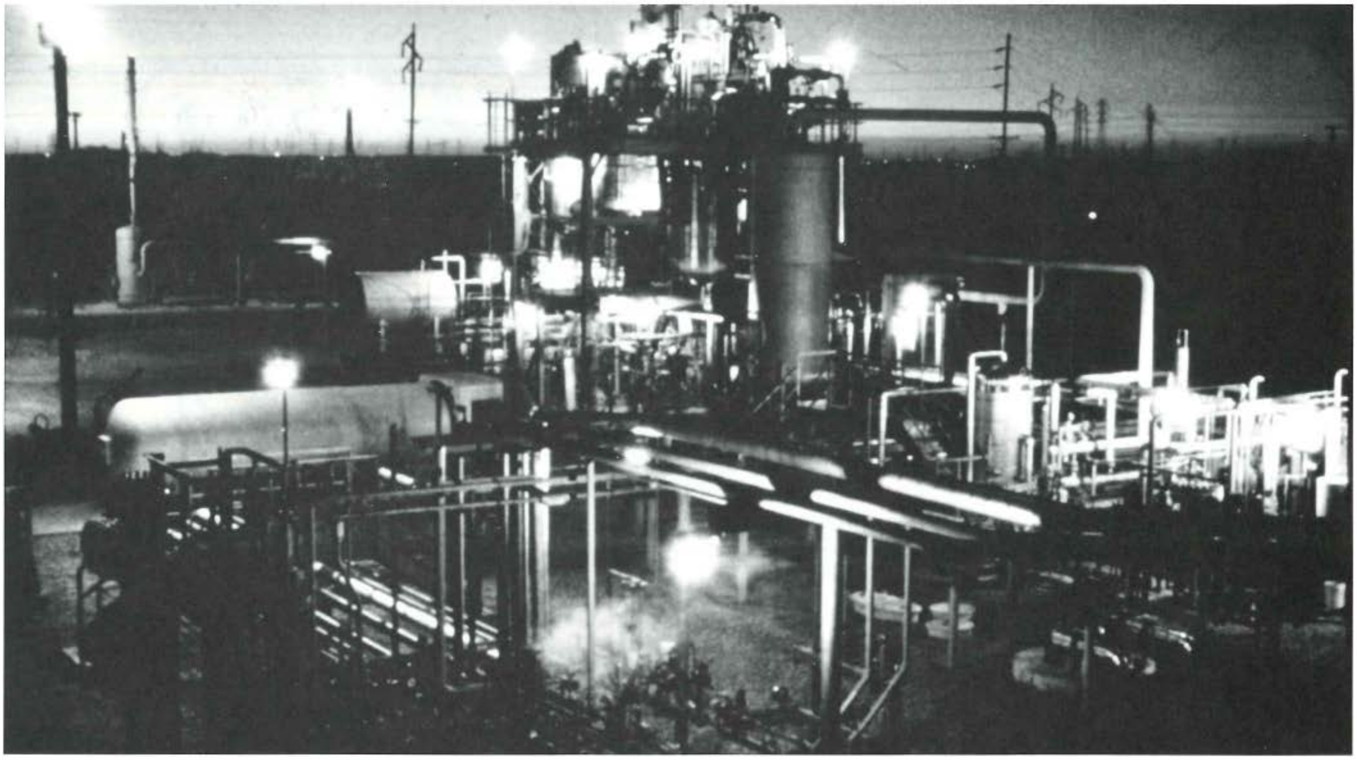


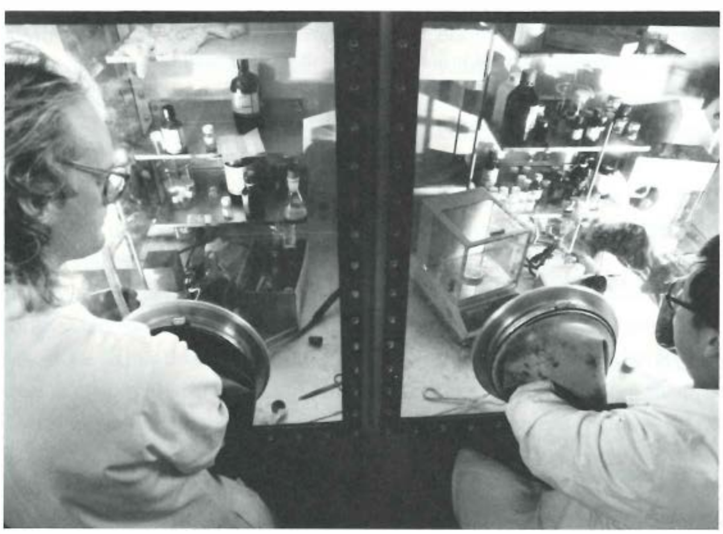
In a novel alternative to the two-step method, chemical catalysts are being developed that mimic the biological conversion of methane by enzymes. The iron-based catalyst captures a methane molecule, adds oxygen to it, and ejects it as a molecule of methanol. If this type of conversion could be performed on a commercial scale, it would eliminate the need to first reform methane into synthesis gas, a costly, energy-intensive step.



Methanol Research

In projects that range from the test tube to near-term commercialization, methanol researchers are working to improve methanol production technology with better catalysts and reactors. An advanced liquid-phase reactor that produces methanol from coal-derived gas has been operated at the pilot plant stage at the synthesis gas generating facility of Air Products & Chemicals in LaPorte, Texas. Coupling such a reactor to an integrated gasification–combined-cycle power plant would allow the coproduction of methanol and electricity; the methanol could be stored for use as a peaking fuel or sold to outside markets. Longer-term research focuses on developing catalysts that operate at lower temperatures and pressures. An ultimate goal is the commercial use of catalysts that simulate the action of natural enzymes in converting methane to methanol at room temperature.





Natural reactions

While chemical engineers strive to improve the efficiency and economics of producing methanol from synthesis gas, scientists at the leading edge of methane research are searching for a more direct path to methanol. The ultimate objective is to convert methane directly to methanol, without first reforming the methane into carbon monoxide and hydrogen. "If that energy-intensive reforming step could be bypassed, the large energy debit that plagues the front end of conventional methanol synthesis processes would be removed," says Kulik. "There are substantial economic and scientific incentives for developing a direct conversion process, and scientists worldwide are working on it, but it's no simple task to activate methane."

Methane *is* converted directly to methanol, and at room temperature and atmospheric pressures—not by chemical plants, but by microorganisms. Bacteria called methanotrophs ingest the methane and with the aid of an enzyme called methano monooxygenase (MMO)—a biological catalyst—readily transform C-H bonds into C-OH bonds to produce methanol. Almost no energy is lost in this conversion, because the energies of the C-H bond and the C-OH bond are practically the same.

In one of EPRI's most far-reaching exploratory research projects, Richard Fish, a catalyst expert at Lawrence Berkeley Laboratory, is devising a way to make methanol that mimics that of the methanotrophs. Over the past two and a half years, Fish and his research colleagues have constructed synthetic catalysts that simulate the MMO enzyme's active site—the business end of the molecule, where the conversion takes place. In a significant scientific breakthrough, Fish's team used these "biomimetic" catalysts to activate methane and produce methanol in small quantities. Fish believes that additional research will enable him to reach the ultimate goal—a direct catalytic conversion with high selectivity for methanol.

Analogous conversions have already been achieved with other hydrocarbons of methane's class. Applying his catalysts to ethane, propane, and cyclohexane (which have more carbon and hydrogen atoms and weaker C-H bonds than methane), Fish has successfully converted them to their corresponding alcohols.

Fish's work has its challenges. The exact structure of MMO's active site, and the actual mechanism by which the enzyme converts C-H bonds to C-OH bonds, are not yet fully understood. And building biomimetic catalysts is an art as much as a science. But the process of building and testing catalysts has served to improve the team's understanding of both the enzyme's structure and the subtleties of the reaction mechanism. This knowledge, in turn, has helped the team construct more effective catalysts and move closer to its goal.

Linda Atherton, who manages basic research in the Fuel Science Program, cautions that bringing biomimetic methanol synthesis from the test tube to a practical commercial process may take two decades or more—if it can be done at all. "It's an exciting breakthrough, but it's too soon to know whether we'll be able to use this on a commercial scale," she says. "But if further research demonstrates that the catalyst can be made economically and used repeatedly, there would be tremendous commercial incentive to use it. We'll have bypassed the reforming step at the front end of the conventional process, which essentially is thermal energy up the stack."

"We're on the ground floor right now," says Fish. "But although this work is long-term, high-risk research, the potential payoff is substantial—it's not pie in the sky." He commends EPRI's exploratory research program for providing sustained support for his work. "The project managers have shown a genuine interest in advancing scientific knowledge," he says. "And they recognize the value of fundamental research that may not be oriented to specific near-term technical goals, but that has the potential for a high payoff in the future. We have to walk before we can run, and fundamental research is important to ensure that the technology will be ready when we need it."

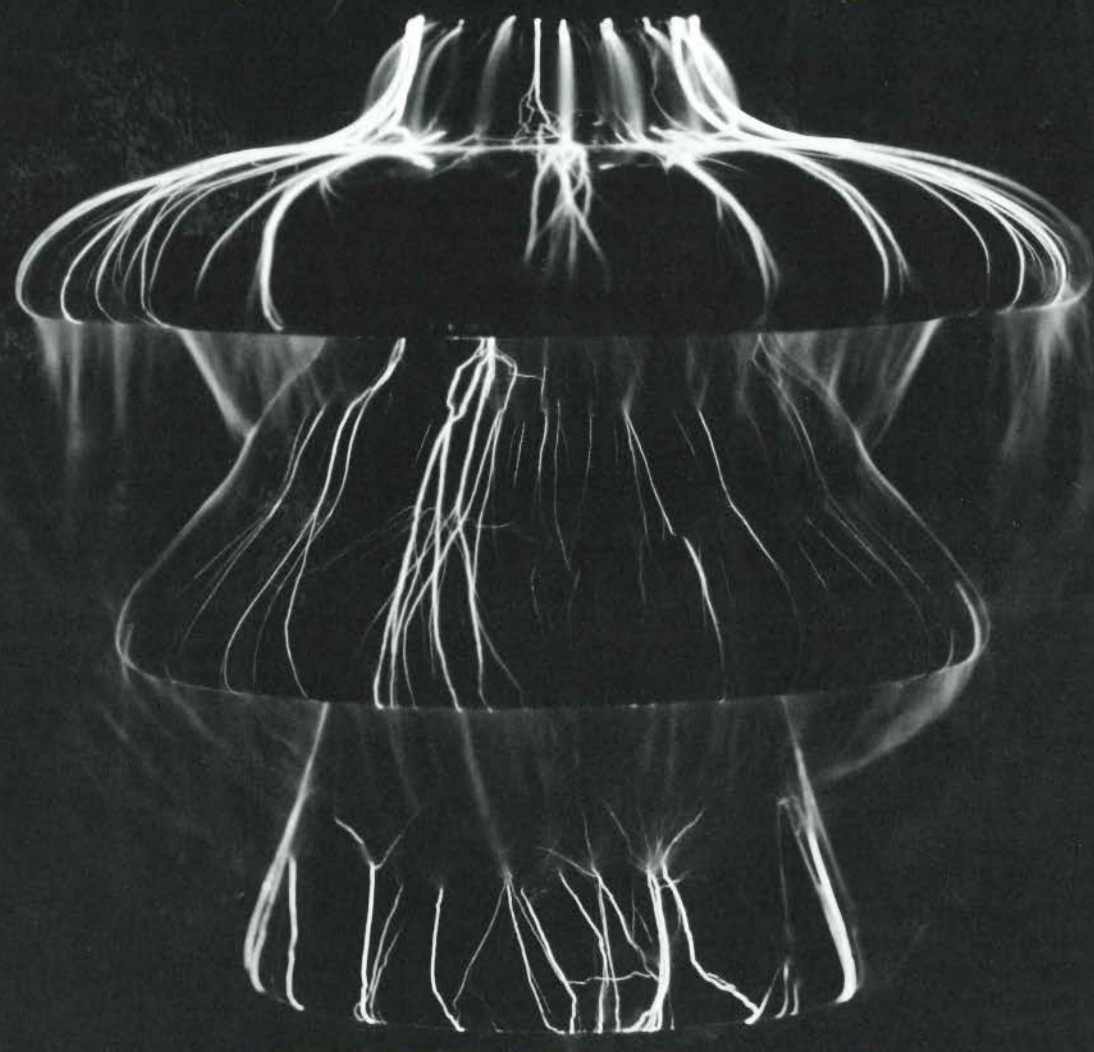
Challenges and opportunities

Methanol has considerable potential to reduce the environmental implications of coal as it becomes the world's predominant fuel source for both stationary and mobile power generation.

Methanol's future in utility operations will be determined by the interplay of several factors, including the price and availability of oil and natural gas and the shape and direction of the nation's emerging energy and environmental policies. As the electric power industry approaches its second century, it faces many challenges. It will require flexible strategies to ensure that future energy demand will be met despite uncertainties in fuel supplies, uncertainties in the regulatory environment, and increasing competition. Through projects that balance near-term applications with long-term exploratory research, EPRI's methanol program is providing utilities with a practical fuel option that can give them the flexibility they need to deal with an unpredictable future—as well as technology that opens new business expansion opportunities to help them remain the low-cost providers of electric power. ■

This article was written by David Boutacoff. Background information was provided by Conrad Kulik, Linda Atherton, Howard Lebowitz, and Michael Gluckman, Generation and Storage Division, and by Richard Fish, Lawrence Berkeley Laboratory.

Huge surges of power caused by lightning and other disturbances can overwhelm a transmission system, bringing on outages and damaging equipment. A greatly enhanced EMTP code allows utility engineers to accurately design and plan for the degree of protection needed to withstand such surges.



DESIGNING FOR DISASTER

Electromagnetic transients are the tidal waves of electric power systems. These momentary voltage surges—generally lasting only fractions of a second—can be powerful enough to disrupt normal operations and even cause serious damage to major pieces of equipment, such as transformers. Created by lightning, line faults, substation switching functions, and other sudden events along a utility network, transients must be taken into account both in choosing equipment ratings for a power system and in setting its operating parameters.

Like the builders of a seawall that must withstand the highest expected waves from the ocean, engineers trying to guard against damage from transients face an extraordinary design task. Most of the huge computer simulation codes related to power systems either model steady-state conditions or deal with system stability problems. The analysis of electromagnetic transients, on the other hand, requires a much more detailed examination of how some critical portion of a power system will react to conditions that can change greatly in microseconds.

For many years, simulation of transient effects was performed by special-purpose analog computers called transient network analyzers (TNAs). These machines, which are still in use, re-create a portion of the power system in miniature—complete with voltage sources representing generators and various kinds of capacitive or inductive loads. TNAs are generally adequate but relatively inflexible, tedious to set up, and cumbersome to use. Once a system configuration is modeled, many simulations can be performed. Given the need to manually reconfigure TNA circuits to represent changes in a system, however, the analyzers can also be quite expensive to use.

During the late 1960s, Herman Dommel of the Bonneville Power Administration (BPA) developed a program that could analyze transients on digital computers, which were then rapidly becoming more powerful and less expensive. Known as the Electromagnetic Transients Program (EMTP), this large computer code soon became an industry standard, used extensively around the world. As computer technology continued to change and EMTP began to expand under BPA aegis, however, utilities encountered increasing difficulty in using the program. The code itself grew from about 5000 lines of programming in Dommel's original version to more than 70,000 lines by the early 1980s. Documentation and maintenance became hard to coordinate. User support was virtually nonexistent.

Coordinated development

Clearly something had to be done. In 1982 the EMTP Development Coordination Group (DCG) was formed to expand the program and make it easier to use. EPRI reached an agreement with DCG in 1984 to take charge of documentation, conduct EMTP validation tests, and add a more user-friendly input processor. The development of new technical features would remain the primary task of DCG itself.

As a result of these efforts, the DCG/EPRI Version 1.0 of EMTP was issued in early 1987. It was supported by a user hotline and a special error-tracking procedure. The enhanced code had been extensively tested and documented in a comprehensive set of EPRI manuals. Many programming bugs reported in earlier versions had been corrected, modeling methods had been improved, and new capabilities had been added. Version 1.0 was well received by utilities, and about 150 copies were distributed. Version 2.0 of EMTP, released in the spring of 1989, includes further improvements.

"EPRI got involved in EMTP development primarily because our members wanted better user support, model development, and documentation," says Mark Lauby, the project manager for Version 2.0. "Since EMTP is one of the largest simulation codes in the electric power industry, a major cooperative effort was needed."

Tracking a transient

"The unique challenges involved in calculating the effects of electromagnetic transients can most easily be understood through an analogy," says Lauby. "For example, envision a small, quiet pool of water in which a rock is abruptly dropped. Waves are created and reflect from the sides of the pool, creating complex patterns, or waveforms. Being able to account both for the initial waves caused by abrupt system changes and for the wave reflections is an important capability of EMTP."

Consider the task of determining how often lightning strikes on a particular transmission line will cause outages. The solution to this problem requires tracking in detail the events that occur on a particular portion of the line during the first critical microseconds after a strike.

Most transmission lines are well protected from direct lightning strikes by shield wires grounded to towers. Sometimes, however, the surge of current caused by the lightning is so great that it causes a flashover between the tower itself and one of the line conductors—a phenomenon called backflash. The frequency of such backflashes depends to some degree on span length, tower height, coupling, and amount of insulation, but the most important factor is how well the towers are grounded, a property that is expressed in a design parameter called tower footing resistance (TFR). The lower the TFR, the more likely a lightning surge will flow uneventfully into the ground rather than flashing over to a line.

Now suppose lightning strikes a tower of a 230-kV transmission system, creating a surge that rises to 1000 amps in 1.0 microsecond. Calculating the maximum voltage at the top of the tower requires taking into account the first reflection of the surge, which returns from the tower footing in about 0.2 microsecond, and a larger reflection from the first adjacent tower, which arrives in about 2.15 microseconds. The typical output from an EMTP analysis of this situation would be a plot of voltage at the tower top. Voltages above a critical level would be assumed to cause backflash.

A designer interested in setting the tower footing resistance of a new transmission line to be built in an area with frequent thunderstorms could have EMTP calculate the frequency of backflashes for different TFR values. In one sample calculation, the result was 19 backflashes per year along each hundred miles of line for a TFR of 50 ohms, compared with only 5 backflashes for a TFR of 20 ohms. Such calculations typically require only 5 or 10 minutes of running time for EMTP on a personal computer.

"Modeling this type of microsecond phenomena requires much more detailed analysis and extensive input data than programs dealing with load flow and transient stability," says Neal Balu, manager of EPRI's Power System Planning and Operations Program. "EMTP provides this important analytical capability, and EPRI's work with DCG has made the program considerably easier to use."

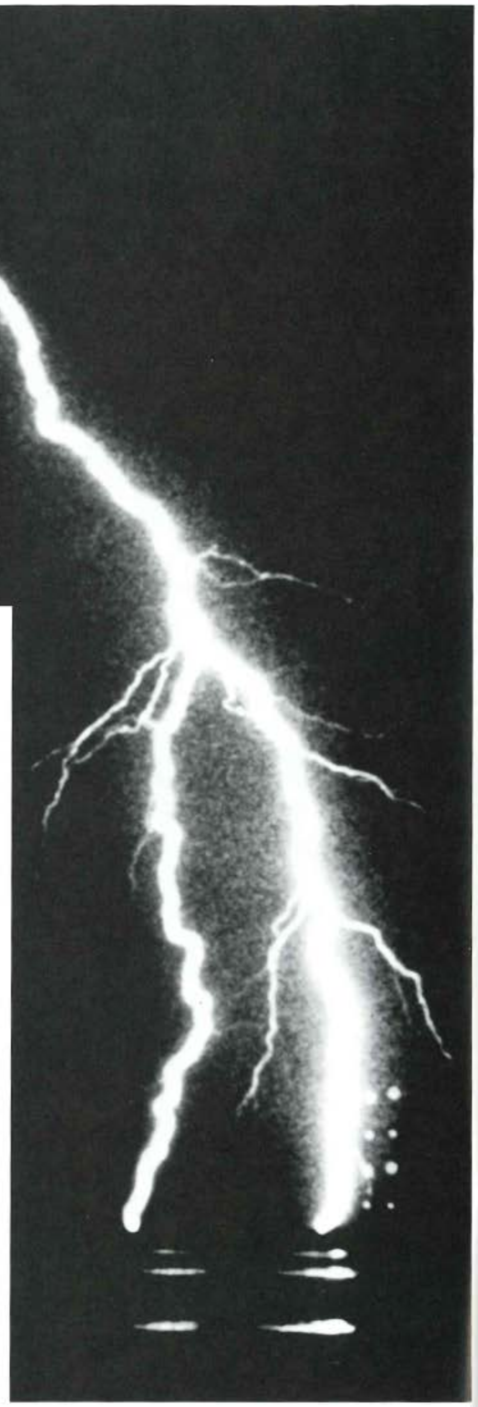
Using EMTP to reduce costs

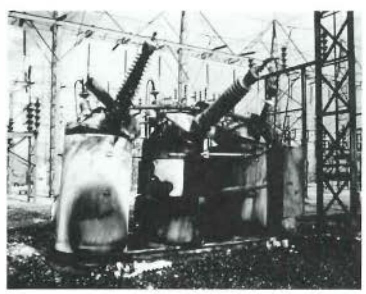
Given the ability to predict the strength and frequency of transients on their transmission networks, utilities can often reduce equipment costs by avoiding unnecessarily conservative designs. The improved versions of EMTP provide utilities with a unique capability for making such calculations efficiently and inexpensively.

By using EMTP to distinguish between surges caused by lightning and those resulting from normal switching operations, for example, a utility can choose optimal discharge voltages for metal oxide surge arresters on its system. Similarly, countermeasures can be selected to guard against the unstable exchange of energy between the mechanical system of a generator and the transmission line to which it is connected. Called subsynchronous resonance, such energy ex-

Prediction for Protection

Inadequate protection against strong electromagnetic transients, such as those produced by lightning strikes, can mean a damaged transformer, a burnt-out circuit breaker, or even a broken generator shaft. The EMTP code can predict the strength and frequency of such transients for utility designers and model these complex disturbances in detail, microsecond by microsecond.





change results from transients on the transmission line and can cause a generator shaft to oscillate so much that it breaks. EMTP has a special feature that models the effects of subsynchronous resonance on mechanical equipment—and thus helps designers plan to prevent such damage.

In addition to aiding design efforts, the program can be used to diagnose common operating problems. Consider, for example, what happens when a substation circuit breaker with a large capacitance opens near a potential transformer. This operation may trap an electric charge that oscillates between the capacitance of the circuit breaker and the inductance of the transformer—a phenomenon known as ferroresonance. EMTP can identify circumstances under which ferroresonance will occur so that appropriate countermeasures can be introduced, such as adding capacitance to the bus connecting the circuit breaker and the transformer.

One of the first major uses of EMTP Version 1.0 to analyze equipment requirements and unusual system operating conditions was made by the Western Area Power Administration. This federal power marketing administration has 250 substations and 16,000 miles of transmission lines in 15 western states. In recent years, it has been upgrading series capacitors on its system, while adding phase-shifting transformers and shunt capacitors. By using EMTP to evaluate such additions in terms of their ability to withstand transients, the administration estimates it has realized present-value savings of nearly $2.8 million.

"Today you could not build a transmission system without EMTP," according to Lauby. "It can also be used to determine the cause of equipment failures after they occur."

Future directions

The popularity of Version 1.0 of EMTP led to the release of Version 2.0 last spring. The new version has several enhancements, including both new models and improvements in existing models. Some of the specific enhancements are an interactive user interface, an algorithm for handling three-phase load flow, a generic model for dc power systems, models for substation spark gaps, and an improved plotting capability.

Comparisons between EMTP results and full-scale system measurements are being made in this country and abroad, which can help users better understand the limitations of the code. General Electric is working under EPRI contract to gather information on existing comparison studies and will soon make this information available to members of EPRI and DCG. Also, as an associate member of the EMTP development effort, American Electric Power is conducting validation studies and developing a three-phase load flow model.

Meanwhile, the French national utility, Electricité de France (EdF), is using EMTP to calculate the effects of transients on a new 2000-MW dc link across the English Channel to Britain. These calculations will be compared with extensive data produced by tests of the ac/dc converter station on the French side, which were conducted before the 1986 inauguration of the line. During these tests, several large transients were intentionally created, producing a unique database for testing EMTP validity.

In addition to EdF, international DCG participants include the manufacturer Asea Brown Boveri and the Central Research Institute for the Electric Power Industry of Japan, which is representing 10 Japanese power companies and 7 Japanese manufacturers. In Japan, EMTP is widely used to make detailed analyses of lightning surges, and it has reportedly enabled utilities to reduce insulation levels on ultrahigh-voltage (1110-kV) transmission lines by using high-performance zinc oxide surge arresters.

The release of Version 2.0 of EMTP represents the end of the current development cycle, which mainly involved improvements to the code rather than basic changes. Next, a variety of more fundamental modifications may be attempted, to take advantage of the significant changes that have occurred in computer technology since EMTP was first created. Modifications being considered include the modularization of the code (to make it easier to maintain), the addition of improved graphics and interactive capability (for increased user-friendliness), and the use of more advanced solution algorithms (to make calculations more accurate and more efficient in their demands on computer time).

"Today's power systems are being pushed to their limits, which means that ensuring they are able to withstand unexpected transients is becoming even more important," concludes Neal Balu. "Systems are also being upgraded, and utilities are increasingly concerned about reducing unnecessary design margins in their new equipment."

EMTP can help in each of these endeavors, according to Rambabu Adapa, the project manager for developing Version 3.0, and further developments will make the code even more useful. "The use of personal computers in the power industry continues to increase," Adapa points out. "To meet growing industry demands, EPRI and DCG have taken on the major task of developing EMTP PC-Workstation, which will be available by the end of 1989. This workstation will provide the user with a powerful interactive environment that includes on-line help, graphic presentation of the EMTP output in a window format, and several other features. We hope that the release of Version 2.0 and development of the workstation will not only bring about wider application of EMTP, which is now considerably easier to use, but also encourage more utilities to join EPRI in this coordinated development effort." ■

This article was written by John Douglas, science writer. Technical information was provided by Mark Lauby, Neal Balu, and Rambabu Adapa of the Electrical Systems Division.

TECH TRANSFER NEWS

Cable-Condition Monitor Ready for Utility Trial

A portable instrument for checking the condition of unshielded power, control, and instrumentation cables is ready for trial use. EPRI is looking for a member utility (preferably nuclear) to include the tool in a systematic condition-monitoring program at a power plant.

Developed by Franklin Research Center, the hand-held "indenter" works by depressing the cable jacket or insulation with a blunt probe and measuring the force per unit of depth. The same principle, but without the precision, is used by an inspector or troubleshooter who tests for embrittled cable insulation by pressing a fingernail into it.

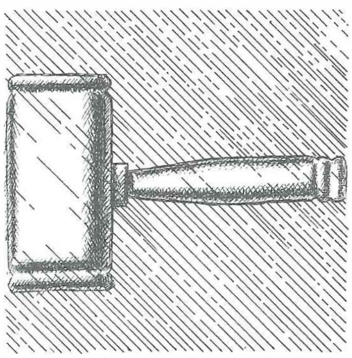
Although safety-related cables in nuclear plants are usually qualified for a full 40-year licensed term, conditions in or near containment buildings could lead to earlier deterioration of cable insulation or jacket material. For example, higher-than-expected ambient or ohmic temperatures can produce premature embrittlement and cracking of polymer insulation. In-place monitoring data from a period of years should be helpful in demonstrating cable longevity and justifying a longer plant operating life, thereby avoiding premature cable replacement costs. ■ *EPRI Contact: George Sliter, (415) 855-2081*

Acid Rain Research Brochure Available

Utilities involved in information exchange with legislators, regulators, and others making decisions that affect acid rain control can turn to a new EPRI publication, *Acid Rain Research Results: An Environmental Briefing*, for a summary of EPRI's 13-year, $85 million research efforts to date. The booklet is intended for use both inside and outside the electric utility industry.

Designed to provide key information in selected areas, the 16-page document presents EPRI findings on such important questions as these: What is the nature and extent of the effects of acid rain? What can be done to eliminate or mitigate identified adverse affects? Would reducing emissions lead to environmental benefits?

Such questions continue to be debated by members of the scientific community, the public, and policymakers. A shortage of concise communications on the issue is making policy decisions particularly difficult. The EPRI summary of scientific conclusions and technological information provides essential background data for responding to proposed legislation.



The new booklet distinguishes between acid rain, acidic precipitation, and acidic deposition, and presents summaries of research results on their patterns, effects, and mitigation with respect to lakes and aquatic life, forests, crops, and human health. There is also a discussion of an EPRI-developed computer program called ADEPT, which allows for explicit consideration of scientific uncertainties and differing points of view on the issue of acid rain. The program allows environmentalists, policymakers, utilities, and other participants in the acid rain debate to form judgments on the value of proposed control and mitigation strategies.

The publication is free to EPRI members, and additional copies are available for a fee. To order the brochure, call EPRI at (415) 934-4212. ■ *EPRI Contact: Steven Lindenberg, (415) 855-2736*

Simplified Load Controller Costs Less

Currently undergoing field-testing by six U.S. utilities, a single new component combines the fault protection features of a standard circuit breaker with the remote control capabilities of a power relay. The hybrid breaker/remote switch (HBRS) is designed for replacement use with motors and appliances that are subject to utility load control, such as electric water heaters, swimming pool pumps, and resistance heaters. The HBRS also can be used to control lighting systems in commercial buildings.

Utilities participating in the testing are Central Maine Power, Northern States Power, Consolidated Edison, Virginia Power, Potomac Electric Power, and Pacific Gas and Electric. The utilities will provide data on technical performance and installation costs for use in establishing savings achieved with the device.

Traditionally, installing load control equipment often requires installing an additional power relay in series with the existing circuit breaker—work that calls for an electrician in order to comply with local codes. To avoid such expense, EPRI and Matsushita Electric Works cosponsored the development of the HBRS. The device eliminates the need to rewire circuits when installing load control equipment.

The HBRS simply replaces the customer's breaker, and the utility's load controller signal wiring connects directly to it. The operation can be performed by utility service crews, so labor costs can be reduced. Material costs should also be lower, since load controllers contain no power circuits and therefore can be made smaller.

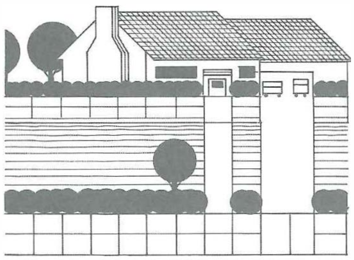
The HBRS has been under development since 1984, and testing is expected to continue through the end of this year. Representatives from Matsushita have assisted the utilities with installation and helped establish test procedures. Underwriters Laboratories has approved the HBRS for use in a variety of commonly used U.S. panel boards. *EPRI Contact: Larry Carmichael, (415) 855-7982*

Cable Replacement Service Minimizes Excavation

Because underground residential distribution cable often is buried beneath sidewalks and landscaping, replacing it is disruptive as well as expensive. The conventional process of trenching and backfilling along the entire cable length requires extensive restoration that often is a major share of the expense. In many cases, though, the problem can be solved by boring.

FlowMole Corp., a utility services firm, uses a self-contained, steerable boring tool that it developed from experience on EPRI-sponsored research. The GuideDril™ cuts soil with high-pressure jets of liquefied clay to create a small clay-lined bore (2 to 6 inches in diameter). The bore can run as long as 400 feet at a depth as great as 30 feet.

The tool makes use of a special remote steering capability that permits workers to maneuver around obstacles, such as sewers and water mains, and even to back up and create a new bore. New cable can then be pulled, passing beneath surface obstacles without disturbing them. The only surface excavation required is a small pit at each end of the tunnel. Lawns, trees, shrubs, driveways, and pavement are undisturbed, and costs to restore the site on completion of the job are sharply reduced.



Baltimore Gas & Electric recently retained FlowMole to install a 1¼-inch high-pressure plastic gas main under a 35-foot-wide stream. The job was done in less than eight hours, saving the utility an estimated three to five weeks of work.

Jersey Central Power & Light (JCP&L) has been using FlowMole's services since 1985. With conventional excavation methods, JCP&L replacement costs in residential areas had ranged as high as $70 a foot. The company's southern district now estimates savings of as much as $40 a foot with FlowMole. *EPRI Contact: Thomas Kendrew, (415) 855-2317*

Planning Ahead for Cable Replacement

Failures of underground residential distribution (URD) cable are costly. So are repeated repairs. "Ideally, we would like to anticipate when and where cable runs are likely to fail and plan ahead to replace them before failure occurs," says Jersey Central Power & Light. JCP&L has developed a computerized database to analyze cable failures, and several other utilities have expressed interest in following its lead. "With much of our cable approaching 20 years of age, replacing entire runs on an emergency-by-emergency basis would pose a financial hardship," says John Vanderipe, line superintendent for JCP&L's southern district.

The utility's program makes use of field interruption reports, which present information on where and when each failure happened, the number of customers affected, the age and type of cable at the site, cable manufacturer, type of splice, and soil condition. Then, when a new failure occurs, Vanderipe and a distribution engineering team examine all past incidents in the same area. If the data show many failures, they may decide to replace a much longer run of cable than has just failed, so as to forestall future failures. Or they may elect to simply repair the failure—a short-term remedy—until additional data indicate another course of action.

The cable tracking and replacement program has enabled Vanderipe to stay on top of more than 600 miles of URD cable. In 1986, for example, Vanderipe's district responded to 98 incidents of cable failure; in 1987, to only 83. In 1988 the number increased to 96, despite the fact that the cable tracking and replacement program was in its third year. "This told me the cable was deteriorating," says Vanderipe. But by September of this year, the utility had experienced only 49 failures. "It looks like we're staying level instead of increasing, despite the increasing age of much of the cable," he concludes.

JCP&L is able to pick and choose where and when cables are replaced and to select the most cost-effective method for making repairs. Even without knowing exact sites, the utility can estimate its requirements a year in advance. "By annually planning and budgeting for cable replacement, we're much more in control of the situation," says Vanderipe.

Omaha Public Power District, Arizona Public Service, Puget Sound Power & Light, Santee Electric Cooperative, Oklahoma Gas and Electric, and Metropolitan Edison all have expressed interest in JCP&L's cable replacement program. *EPRI Contact: John Marks, (415) 855-2294*

Demand-Side Planning

Evaluating Cogeneration Options

by Hans Gransell, Customer Systems Division

An increase in cogeneration was perhaps one of the first signs that a restructuring process was occurring in the electric utility industry. Caused in part by the Public Utility Regulatory Policies Act (PURPA), changes in the industry have been characterized by an increase in competition and a decrease in fuel prices. The rise of cogeneration has been a response to these industry changes.

While the word *cogeneration* did not become commonly known until the 1978 National Energy Act, the concept of cogeneration is not new. Early in this century, most U.S. industrial firms generated their own electricity, with 50% to 60% of total electric energy being generated on site. Much of this on-site generation was cogeneration. On-site generation was used by industry because it was more reliable and less expensive than utility-generated power, and this approach became standard practice.

In the 1930s federal and state regulation expanded utility service areas. Moreover, a reduction in fuel policies and advances in generation and transmission technologies made centrally generated electricity inexpensive compared with on-site generation. As a result, industrial firms replaced on-site generation or cogeneration with utility purchases. By 1977 cogeneration had declined from 50% to about 3% or 4% of total U.S. electricity generation. In part because of PURPA, this downtrend was reversed, and by 1986 cogeneration capacity stood at about 25,000 MW, installed mainly in energy-intensive industries. This amount could double during the next 10 years, and by the year 2000, depending on what happens with competitive bidding in different states, cogeneration could provide 7% to 10% of U.S. power generation.

Current utility attitudes concerning cogeneration differ sharply. Utilities with adequate capacity generally consider cogeneration to be a threat to their business. If cogeneration customers leave a utility's system, the result may be reduced electricity sales and a decreasing market share for the utility and increased electricity costs for the remaining customers. Other utilities view the installation of cogeneration facilities as a potential supply opportunity; the integration of cogeneration units into their systems often allows these utilities to add capacity at costs lower than those of conventional utility supply alternatives.

Regardless of how utilities perceive cogeneration, its growth may significantly affect load shapes, revenues, and rates. For most utilities, the short-term results of increased cogeneration are a reduction in revenues and an increase in rates. In the long term, however, cogeneration may offer benefits, such as a reduced need for new generating capacity.

A key dilemma for utilities facing large cogeneration market potential is the trade-off between the short-term negative impacts and the possible long-term benefits. Recognizing that cogeneration is an attractive option for many industrial and commercial customers, several utilities have established subsidiaries to actively participate as owners or co-owners of cogeneration projects. Many utility managers believe that cogeneration is a natural extension of a utility's business and that utilities are the most qualified to design, construct, operate, and manage cogeneration facilities.

ABSTRACT *In response to recent industry changes, utilities are showing increased interest in the cogeneration option as a way to competitively manage their operations. The EPRI-developed COGENMASTER computer model is an effective decision maker's tool that helps utilities advise their customers who are considering cogeneration projects. COGENMASTER is also useful in helping utilities decide whether a cogeneration option should be pursued and, if so, what role they might play in becoming directly involved.*

COGENMASTER

EPRI's involvement in cogeneration research dates back to 1977 and has focused on utility roles, perspectives, and impacts. Of special interest have been the feasibility and benefits of cooperative efforts and joint ventures between industry and utilities. In December 1988 EPRI released COGENMASTER, which has since been widely distributed to member utilities. With COGENMASTER, utility planners and customer service and marketing representatives can evaluate the technical and financial feasibility of various types of cogeneration systems for commercial and industrial sites. This PC-based model simulates the performance of alternative cogeneration systems under different operating strategies and ownership arrangements. It can help in developing an understanding of whether cogeneration is an appropriate option for a given application and can provide an indication of the best sizing and ownership alternatives.

The model consists of two sections (Figure 1) that simulate the technical and financial performance of cogeneration systems. The technology section can do the following:

▫ Screen alternative cogeneration technologies on the basis of site-specific technical and installed-cost criteria

▫ Compare each cogeneration alternative with the facility's existing system

▫ Evaluate alternative system sizes on the basis of the facility's thermal and electric loads

▫ Assess performance under different operating modes

COGENMASTER's financial section uses results from the technology section to do the following:

▫ Evaluate the economic impacts of a wide range of financing and ownership arrangements for potential utility, customer, and third-party developer

▫ Forecast capital cost and operating cash flows over the system's useful economic life

▫ Apportion cost estimates among participants to identify beneficial ownership structures and distribution of after-tax costs and benefits

The technology section can be used without the financial section for initial screening. Users can quickly assess the viability of a wide range of options before proceeding with a detailed financial analysis.

COGENMASTER facilitates a number of analyses that are not possible with current software models on the market or through engineering feasibility studies alone. For example, changes over the last few years in tax regulations and depreciation schedules governing cogeneration have made possible a variety of new ownership and financing arrangements including joint ventures, partnerships, and third-party financing. COGENMASTER can analyze the financial impacts these different arrangements will have on all potential participants in a cogeneration venture.

COGENMASTER's technology and financial sections both have input, simulation, and output modules. The modular approach facilitates user access to all data parameters and output reports. Inputs to the technology section include cost and performance data on equipment, rate structure, load, system size, and operating mode characteristics for different cogeneration systems. Ownership and financial arrangements for the cogeneration venture are defined in the financial section.

COGENMASTER's technical simulation module compares the economics of each proposed cogeneration system with the economics of the noncogeneration system. With these data, the financial simulation module then calculates the costs and savings for the various participants. Users can also simulate, via the technology section, the performance of a variety of cogeneration systems as a preliminary rough screening of options. Having narrowed the field of choices, users may enter data on the most promising choices into the financial section.

Software portability is another attractive feature of COGENMASTER. If an IBM-compatible personal computer is available, utility marketing or customer service representatives can

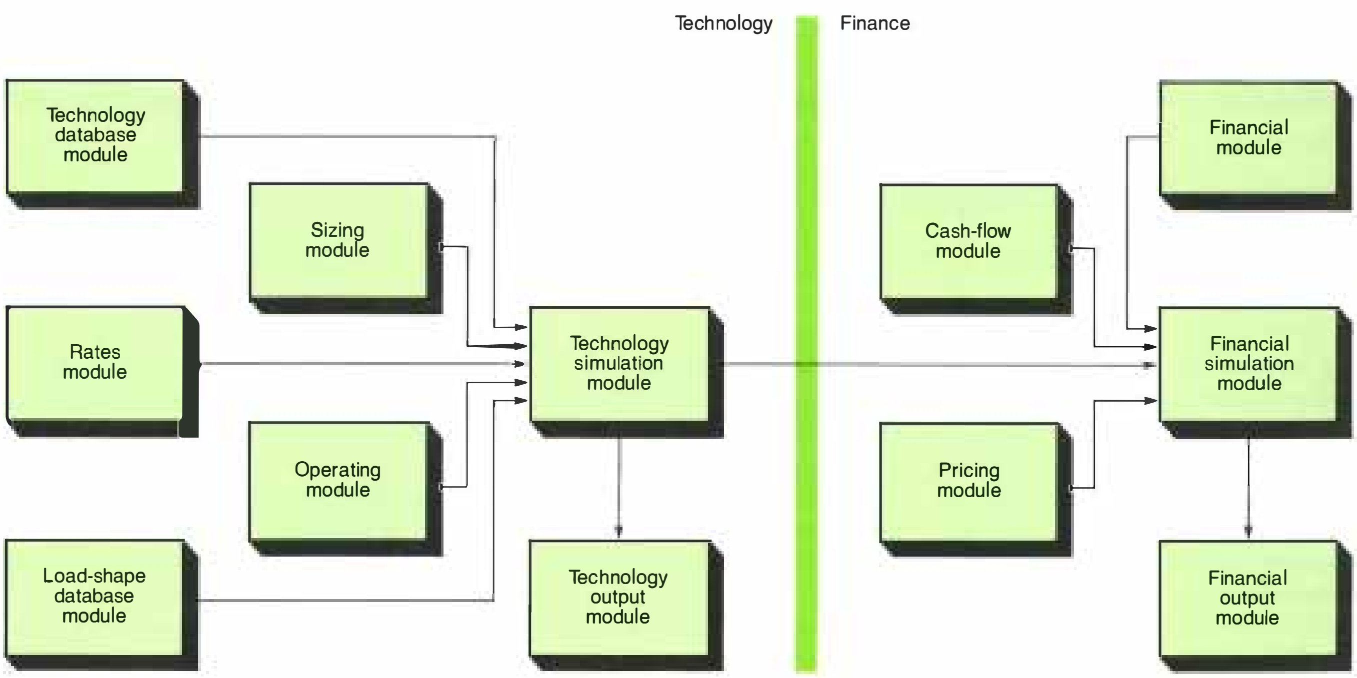


Figure 1 **COGENMASTER has two major sections that simulate the technical and financial performance of cogeneration systems. The technology section simulates the physical operation of alternative cogeneration systems and develops economic data. The financial section uses the economic data to develop cash-flow information under several possible ownership scenarios.**

perform a quick analysis of cogeneration options in a client's office. Results can be discussed immediately, potentially eliminating the need for time-consuming repeat visits.

Input requirements

Menu-driven and user-friendly, COGENMASTER incorporates explanatory help screens to guide the user through the data input process. Default values are provided for almost all input data. In the technology section, the user can specify the performance, installed cost, and fuel characteristics of different cogeneration technologies. The rates module allows the user to handle both time-of-use and block rate structures. The user can specify up to four seasons and three types of periods (on-peak, partial-peak, and off-peak). The user can also input six rate periods per day, which can be different for weekdays and weekends and for demand and energy charges. Charges for cogeneration include a standby charge, a maintenance power charge, and a backup (supplemental) power charge.

Facility thermal and electric loads can be entered into the load module for every hour of the year, for three typical days of the year, or for three typical days for each month of the year. The sizing and operating modules permit consideration of a variety of alternatives and combinations. The system either can be sized to meet a specified load—base or peak, summer or winter, electric or thermal—or can be defined in terms of kilowatts. Different modes of operation can be specified, including electric-load following, thermal-load following, or constant-output operation.

In the financial section, COGENMASTER requires information relating to ownership structure, to the installed cost for different categories of equipment under various rules for depreciation required by PURPA, and to the project participants' contributions to both capital costs and the servicing of long-term debt.

When evaluating potential cogeneration projects, the most time-consuming work is data collection—not only technology cost and performance data but also load-shape data. Thus, important features of COGENMASTER are the built-in technology database and load-shape library.

Utility experience

More than eighty utilities have requested copies of COGENMASTER for use in cogeneration evaluation, and several have already reported significant benefits. Using the results of a COGENMASTER analysis, San Diego Gas & Electric persuaded a large industrial customer with a cogeneration plant to use its self-generating capacity only during the peak-demand hours. In this case alone, SDG&E is realizing savings of more than $500,000 a year in recovery of fixed costs. The utility is also achieving savings in reduced staff time.

Public Service Electric & Gas of Newark, New Jersey, finds that with COGENMASTER it can use, for the first time, detailed site-specific information available from customers to provide them with a thorough analysis of potential cogeneration performance.

Central Power & Light of Corpus Christi, Texas, is using COGENMASTER instead of manual methods to calculate the costs and benefits of cogeneration for its customers. The utility estimates it has reduced the staff time required for analysis by 90%.

COGENMASTER will run on any IBM-compatible personal computer with DOS Version 2.11 or higher, a base memory of 512K, a 360K or 720K floppy drive, and a hard disk. The model can be ordered from the Electric Power Software Center, (214) 655-8883, and is maintained for EPRI by Synergic Resources Corp.

Utility Planning

Strategic Cost Management

by Edward Altouney, Utility Planning Methods Center

As the business environment for utilities grows both more competitive and more turbulent, companies need new ways of operating to maintain profitability and a competitive edge. Strategic cost management has proved to be an effective solution for many companies both within and outside the utility industry. In a recent research initiative (RP3026-1), EPRI informally surveyed utility executives who have successfully implemented cost management programs, and reviewed the writings of leading cost and quality management thinkers. A common theme emerged from this research: success in strategic cost management stems both from the selection of an appropriate system or set of tools and from the use of a coherent and well-defined implementation process. Clearly, even the best set of cost management tools, systems, and methodologies will yield poor results if not well implemented and thoroughly integrated into the ongoing management of the company.

The broader EPRI research effort of which RP3026-1 is a part is focusing on the development of specific strategic cost management programs and systems. That research will cover a wide range of cost and quality management opportunities in the electric utility industry. It will develop innovative approaches to materials handling and management, maintenance, resource allocation, productivity improvement, and production scheduling. It will also develop a strategic approach to making plant improvement investments. Plant and equipment management research will provide a business management basis for engineering research being conducted in other divisions at EPRI.

Earlier EPRI research developed new approaches to managing the fuel component of utility production costs. That research effort demonstrated the opportunities that exist to develop new cost management tools for use in controlling other utility corporate cost and productivity issues.

In contrast to this larger research agenda, RP3026-1 addressed the implementation process itself. This effort has resulted in a report that details the components critical to the successful implementation of a strategic cost management program.

The specific set of management activities and processes defined in RP3026-1 can be regarded not as strategic or operations management activities, but as activities for managing change. An appropriate metaphor for strategic management is choosing the best road from among many alternative paths to achieve the organization's objectives. Operations management is running well on the chosen road. Change management, the focus of this research effort, is the building and traversing of a connector to take the organization from the old road to the new.

To provide maximum value, a new strategy must become thoroughly integrated into the day-to-day operations of the company. This is especially true for strategic cost management, for which no shortcut exists. Once an organization has made the strategic choice of cost management, four elements—a common goal, demonstrated management commitment, optimal staff deployment, and a system of feedback and rewards—form the basis for successful implementation. The right strategy and the steps toward implementation are supported by the element of clear communication. EPRI's research has produced not only a detailed understanding of these individual implementation elements but also a structured process that integrates them (Figure 1).

When all these elements are in place and integrated, an organization is empowered—from top to bottom and across all functions—to achieve the chosen strategy. In the case of strategic cost management, this means that all employees understand how they can contribute to managing the organization's costs and are actively engaged in doing so as an everyday part of their jobs.

ABSTRACT *Today's rapidly changing, competitive business environment has made strategic cost management a priority for many utilities. An EPRI research initiative has identified the fundamental elements for successfully implementing strategic cost management programs and has specified the critical components of the process for incorporating these elements. The research findings stress implementation as the key to cost management, and an understanding of how to create and manage change as the key to successful implementation. As an aid to utilities, EPRI has developed a framework for integrating cost management tools and systems into the ongoing management of a company. Rather than a catalogue of individual tools and programs, this framework provides a rigorous discussion of the implementation process itself, as well as specific advice on managing change.*

A common goal

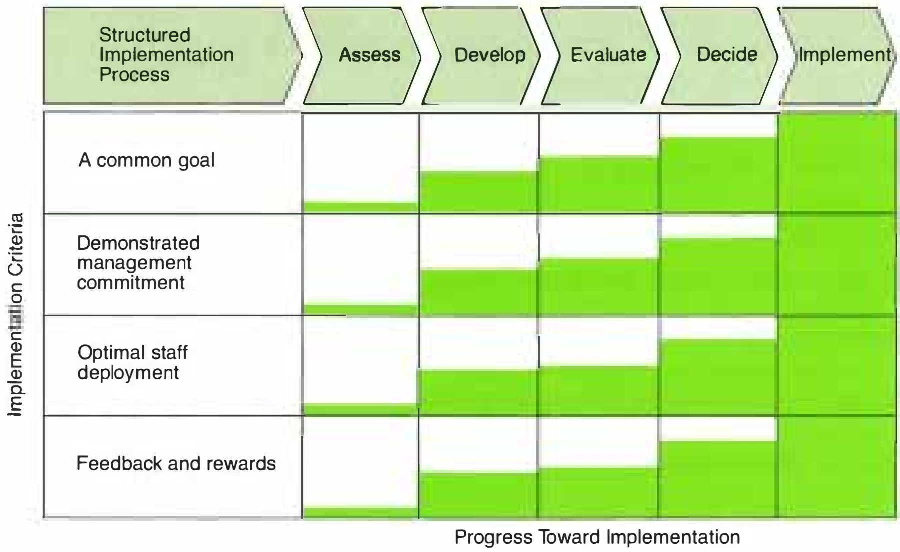
An executive team usually chooses strategic cost management in response to external pressures. The nature of those pressures and their effect on the profitability of the company are clear to top management. Often they are not as clear to the rest of the organization. A clearly articulated and widely communicated common goal gives employees the opportunity to understand and support strategic cost management. Without this critical first element, employees may pay lip service to cost management while continuing to work in the same old ways, or they may actively resist the implementation of cost management programs, fearing that their jobs or their salaries are in jeopardy.

To be effective, the statement of the common goal must be well formed—clearly defined, congruent with the company's past and current performance, and readily communicable. Goal statements can sometimes be shortened to simple themes that both focus internal activities and provide an approach to external communications. ("Quality is job one" at Ford and "The quality goes in before the name goes on" at Zenith are examples.)

An organization must carefully form its goal statement, communicate it widely, and periodically verify that the goal is understood and accepted. There are four simple criteria for success:

- Employees must believe that the company's success is also their success.
- Employees must clearly understand the goal statement and be confident about the roles their jobs play in achieving the goal and about the contributions they can make.
- Employees' actions, attitudes, and behavior must be aligned with the goal.
- Employees must believe that the goal is attainable, is consistent with the organization's purpose, and will enhance the organization's success.

Figure 1 Successful implementation of cost management requires both a set of key elements and a systematic process for putting those elements in place. Shown here is a strategy selection process that enables a company to make cost management a companywide priority.



Demonstrated commitment

Once the first element in the implementation process is complete—that is, the goal of strategic cost management has been clearly defined and widely communicated—employees look to management to see if this is a genuine effort to change or "just another program."

In organizations that have successfully implemented cost management programs, executives and managers have demonstrated their commitment to strategic cost management in four basic ways: providing the financial resources necessary to implement changes, providing the necessary human resources, devoting management time to supporting and monitoring the implementation process, and making symbolic gestures that support cost management.

If change management is thought of as building and traversing the connector from the old road to the new, the need for both financial and human resources is evident. The EPRI research clearly indicates that successful cost management efforts stress the allocation of both adequate budgets and adequate staff. Another resource that managers can use to demonstrate their commitment to strategic cost management is time. In one organization this was referred to as "putting your calendar where your mouth is."

Symbolic gestures in support of strategic cost management vary widely from organization to organization. Much publicized are the cases where top management sells the corporate jet as a gesture of its commitment to cost management. Yet many less dramatic but equally effective actions can be found in the literature—for example, closing executive dining rooms and cutting back on executive bonuses.

Optimal staff deployment

The true test of a strategic cost management program lies in the performance of the organization. The best goal, supported by management commitment, will not overcome poor organizational performance. Companies that have achieved their cost management goals report deploying their employees in jobs and tasks that are aligned with these goals.

The experiences described in the survey responses range from minor adjustments to full-scale organizational design efforts, but they generally have a common theme: success comes from going beyond job descriptions and basic skill sets. Although these two characteristics are important in determining the contribution an employee can make, other aspects must be also considered: general business knowledge, beliefs and expectations about the company, competence, work style, and fit with the corporate culture. A management team typically asks the following kinds of questions as part of this exercise:

- Are jobs defined appropriately to achieve cost management?
- Do decision levels, reporting relationships, and functional groupings make sense, given the goal of cost management?
- Are the right people in the right jobs to make the best contribution?

Participants in this research initiative described a variety of approaches to achieving the staff deployment goal. Three principles stand out, regardless of the approach taken: keep the process as objective and nonpolitical as possible; decide early whether layoffs, attrition, lateral transfers, training, and the like will be used, and then communicate this decision widely; and investigate a wide range of alternatives for bridging the gap between the current situation and the goal.

Feedback and rewards

Feedback about progress toward the goal is critical to the implementation of any organizational change. This is especially true in moving toward strategic cost management. Feedback can provide valuable information at all levels of the organization to allow for course correction and improvement. For individual employees, feedback becomes a powerful motivator for achieving cost management in their work areas and striving for continuous improvement. Participants in this research initiative created and used feedback systems extensively as part of their cost management implementation efforts. Great care must be taken in the design of a feedback system, however. The following are some important guidelines:

- Select appropriate measures for ongoing monitoring.
- Ensure that feedback mechanisms actively support the desired behavior.
- Recognize feedback with rewards that are fairly administered and consistent with the goal of cost management.
- Design both feedback mechanisms and reward systems to be sufficiently flexible and dynamic to adapt to changing needs and conditions.

Clear communication

Adequate communication—about the strategy, the goal, the change management activities, and progress toward the goal—is essential to the implementation of any major change.

The utility executives surveyed said they missed no opportunity to talk about cost management and its importance to their organizations. Cost management showed up in informal conversations, on formal meeting agendas, and as a feature story in company newsletters. It was the topic of discussion for middle management meetings, employee focus groups, and press conferences. The message to managers is clear: use every opportunity to communicate with your employees about your plans for and progress toward cost management. As one utility executive said, "There is no such thing as too much communication." Too little communication, on the other hand, is a commonly reported reason for failure in change management.

Structured implementation process

When top management selects cost management as a strategic initiative, middle managers, supervisors, work team leaders, and employees throughout the company must make the strategy happen in their areas. The question they address is, How can we best make this strategy happen here, in this division, department, or work team? A structured implementation process— the last element in the systematic approach to strategic cost management makes it possible to answer that question.

In the first step of the structured implementation process, an assessment is performed. With the current situation and the goals of the cost management strategy clearly understood, the gap between them can be defined. The second step is to develop alternatives for bridging the gap. Because decision quality depends on the generation of multiple, clearly distinct, creative alternatives, this is a critical step. In the third step, the alternatives are evaluated for feasibility, cost, time, probability of success, and the like. On the basis of this evaluation, a decision is made—a single alternative is chosen. A plan that defines the specific steps the group will have to take to implement the alternative can then be created.

As this process is reiterated across the organization, cost management begins to take hold in the behavior of the employees directly involved in making local decisions and creating local implementation plans. Organizations that have successfully implemented cost management report two major advantages to using this kind of structured process. First, it ensures a level of consistency across the organization. This not only enhances the success of the strategy but also begins to break down some functional barriers and to encourage communication and cooperation between groups. Second, it allows middle managers, supervisors, and employees to work directly with a corporate strategy and make it successful in their work areas. This ensures commitment and cooperation throughout the organization.

When all the elements represented in the systematic approach are addressed, the result is empowerment. The utility executives who participated in this research initiative described their organizations as empowered. Said one, "Individual employees throughout the organization are taking responsibility for solving problems that occur in their area and finding new ways to improve cost-effectiveness. They feel engaged in the process and committed to our success." And another executive commented, "Decisions are made and carried out at the level where the most information exists about the situation."

The results of EPRI's initiative show that if the systematic implementation framework is used, a utility senior management team can create an organization where all employees take personal responsibility for managing costs.

Commercial Program

Cool-Storage Supervisory Controller

by Ron Wendland, Customer Systems Division

Conventional control techniques for cool-storage systems rely on a preprogrammed, timed schedule for chiller and storage system operation. This control strategy minimizes electricity costs for a design-day profile. On nondesign days, which occur 90% of the time, maximum cost savings may not be achieved. For example, a preprogrammed schedule cannot take into account unexpected changes in weather or other conditions that might influence the need for building air conditioning. Consequently it cannot always accurately estimate the amount of storage required or the rate at which the stored energy should be used.

EPRI has sponsored the development of new software the Cool-Storage Supervisory Controller (CSSC)—that improves system efficiency and reduces operating costs. Compared with conventional control systems, the CSSC has enhanced capabilities for predicting next-day ambient conditions and cooling needs, for measuring the difference between predicted conditions and actual cooling demand on an hourly basis, and for rapidly changing operating strategy—switching from chiller to storage or storage to chiller—on the basis of differences between actual and predicted conditions.

Cost savings are the CSSC's most important benefit. An analysis of a typical West Coast office building has shown that installing the CSSC to control a cool-storage system can result in additional cooling cost savings of up to 30% over the savings available with a conventional, time-sequenced controller. (The build-

ABSTRACT *Now owners and operators of commercial buildings can achieve even greater cost savings on space cooling by using the Cool-Storage Supervisory Controller (CSSC) to manage cool-storage systems automatically and efficiently. Designed to take advantage of advanced concepts in energy management systems, this microcomputer software ensures the most cost-effective use of both stored energy and direct-chiller operation to meet building cooling requirements. As part of its ongoing research program in cool-storage technologies, EPRI commissioned Honeywell to develop software for optimal control of cool-storage systems. The Cool-Storage Supervisory Controller is now available for use with commercial building energy management systems.*

ing chosen for the analysis relied on cool storage for 70% of its design-day cooling needs. Savings from the CSSC vary according to building load profile, storage system size, and the applicable utility rate structure.)

How the CSSC works

The CSSC uses a set of control algorithms—organized step-by-step procedures—to determine the most cost-effective cool-storage operating strategy for meeting the next day's predicted cooling needs. In selecting the operating strategy, the CSSC takes into consideration the particular plant configuration, the cool-storage design (partial or full storage), the storage type (chilled water, ice, or eutectic salts), the utility rate structure (up to three rate periods), and noncooling electrical load profiles.

The CSSC control algorithms perform three basic functions: temperature prediction, load prediction, and, most important, selection of an operating strategy. These adaptive algorithms update the ambient temperature profile, load profile, and operating strategy hourly throughout the day by comparing actual measurements with the predicted values.

Daily ambient temperatures and building load profiles are stored in CSSC history files. Once a day, the user enters the high and low ambient temperatures predicted by the National Weather Service for the next day (If a new forecast is not input, the previous day's actual temperatures are used.) The CSSC uses the forecast temperature extremes, plus historical temperature profiles, to predict the following day's ambient temperature profile. These predictions serve as initial estimates only and are corrected hourly, as necessary, for consistency with measurements of actual temperatures.

The CSSC's load prediction algorithms forecast the building's cooling load profile for the following day. The CSSC uses the historical load and temperature profiles to construct a mathematical model of the building. The predicted load profile is adjusted for holiday schedules, partial building occupancy schedules, and for morning "pull-down" loads on days after holidays and weekends.

The most important feature of the CSSC is its ability to formulate control strategy algorithms that compare the cost of using direct chillers with the cost of using storage and to select the least expensive option. Through this feature the CSSC controls the storage system to achieve the lowest possible electricity costs. The predicted temperatures and cooling load profiles, as well as the predicted noncooling electrical load profile for the building, are used to plan the optimal energy management strategy. This strategy is modified throughout the day on the basis of actual conditions.

The CSSC strategy algorithms determine the amount of storage required for the cooling cycle and also the optimal times for charging the storage system, taking into account the current storage inventory, utility rate structures, and any equipment limitations with respect to system capacity or efficiency. The direct chillers are used if the costs justify their operation or if the building cooling load is greater than can be served by available stored energy.

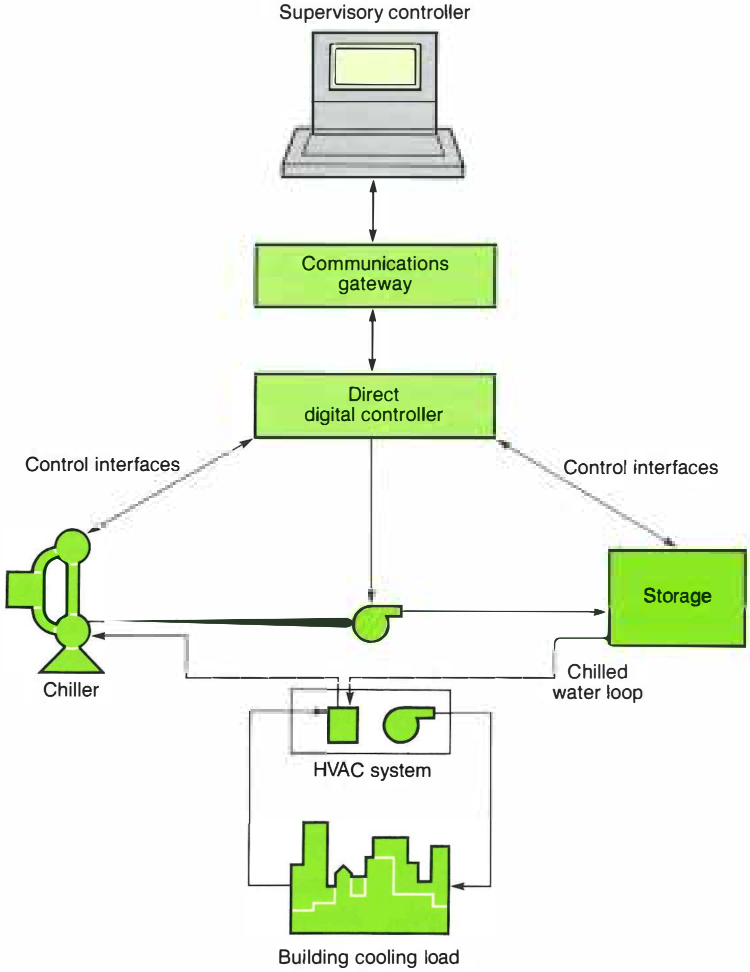
In planning direct-chiller use, the CSSC first searches for valleys in the building's noncooling load profile and schedules chiller operation for those periods, in order to avoid setting new demand peaks. Then, if necessary, it increases the building's demand level uniformly, again avoiding the creation of new peaks, until the entire predicted load can be met. Where multiple electricity rate periods are in effect, the CSSC takes into account the costs of using direct cooling versus the costs of using storage at different times of the day.

Components and installation

The CSSC consists of a supervisory controller, a direct digital controller (DDC), and a communications gateway that connects the two (Figure 1):

▫ Supervisory controller. The CSSC's control algorithms for predicting temperature and cooling load and devising energy management strategies reside in the supervisory controller. This microcomputer directs the DDC's operation by transmitting set points for chiller power consumption and total building power consumption.

Figure 1 Components of the Cool-Storage Supervisory Controller. On the basis of instructions from the supervisory controller, the direct digital controller governs chiller operation and storage charging and discharging.



▫ Direct digital controller. By executing the instructions given by the supervisory controller, the DDC governs chiller operation and storage charging and discharging.

▫ Communications gateway. This is the means by which the supervisory controller interacts with the DDC. The gateway transmits the supervisory controller's instructions to the DDC by modifying appropriate control parameters in the DDC.

Putting the CSSC into operation is a straightforward matter. Some of the sensors required by the CSSC are standard to many energy management systems; generally, the only components that must be added to an existing energy management system are water temperature sensors, an inventory sensor, an outdoor temperature sensor, and a flow meter. The CSSC is essentially self-teaching: with no prior information about the building, it is able to develop a parametric model of the building after a few days of collecting cooling load, electrical load, and temperature profile data.

The user supplies the following information once, upon initial installation:

▫ Utility rate structure—number of rate periods, demand charge, and energy charge

▫ Approximate building design load

▫ Maximum ton-hours of storage capacity, maximum chiller cooling rate, and maximum storage discharge rate in tons

▫ Weekly building-use schedules

▫ If available, startup values for cooling load profile, noncooling electrical load profile, ambient temperature profile, and coefficient of performance of chillers during storage and direct cooling

Field-testing

The CSSC was field-tested at an Alabama Power building in Montgomery. The building's cooling plant consists of a 400-ton-hour Calmac ice storage system and a four-stage, 60-ton Trane chiller.

A chiller priority control strategy was used prior to the time that the CSSC was installed. Under this control strategy, stored energy was not exhausted by the end of the day in shoulder months (fall and spring) and on low-load days. With the CSSC stored energy was fully utilized, and total building demand was held to a minimum.

The CSSC's full cost benefits were difficult to measure from the test results because several different rate structures were tested during the monitoring period. However, the data collected were used in simulations to compare the performance of the CSSC with that of the time-sequenced chiller priority control strategy previously used. The results showed estimated savings of more than 30% in the spring and fall months and more than 5% in the summer months.

CSSC features

The CSSC optimizes cool-storage system operations and maximizes energy cost savings by predicting daily building cooling loads; ensuring that enough storage is available to meet load during the peak period; ensuring the full use of storage on low-load as well as high-load days; operating chillers, if needed, during valleys in the building's demand level, thus avoiding any potential increase in the peak electricity demand; and determining whether storage should be used only during periods when demand charges are in effect, or if there are benefits to using storage in other periods as well.

The CSSC can be used with most energy management systems. It is available for licensing from EPRI or as part of the Honeywell Excel Plus/MicroCentral product.

Utility Planning

CATALYST: Designing Flexible Business Strategies

by Stephen Chapel, Utility Planning Methods Center

In the past two decades, the business environment of electric utilities has been transformed by a variety of economic, technological, and political forces. In addition to higher costs and more stringent environmental regulations, utility decision makers today must contend with emerging competition from other energy sources and from nonutility electricity producers. Also making their job more complex is the growing range of utility supply and demand options—including advanced generation technologies, plant life extension, demand-side management, and service differentiation.

But perhaps the most significant complicating force in today's environment is the increased uncertainty that characterizes nearly every planning factor, from world events to technology cost to customer behavior. Because of this pervasive uncertainty, utilities can no longer afford to plan on the basis of one expected future. The risks associated with inaccurate, inflexible plans are too great—and, in the face of increasing competition, the stakes are too high.

Working with Applied Decision Analysis and Putnam, Hayes & Bartlett, EPRI has developed a systematic procedure for designing flexible business strategies under uncertainty (RP2631). Called CATALYST, this new planning tool provides a framework for analyzing difficult business problems. It is designed to help utilities think about and prepare for the future in a logical, comprehensive way. It is not a computer model but rather a process for structuring decision problems so that models and other planning resources can be utilized more productively.

ABSTRACT *Utilities operate in an increasingly competitive, uncertain business environment. To manage the risks and capitalize on the opportunities in this environment, they need flexible business strategies that spell out explicit responses to a range of possible future events. Using a case study approach, EPRI has developed a powerful decision support tool called CATALYST to help build such strategies. CATALYST is a detailed process for structuring business decision problems and for analyzing interdependent issues and options. It is not a computer model; rather it is a framework that guides the use of existing planning models for specific issues. A preliminary guidebook and training support for CATALYST are now available.*

CATALYST helps planners perform three key tasks:

- Construct a set of plausible future scenarios
- Identify key sources of risk and opportunity
- Develop and evaluate flexible decision strategies to manage risks and capitalize on opportunities

CATALYST is applicable to a wide range of issues and timeframes. The decision can involve immediate actions, contingency plans, or broad strategies. In each case the framework provides a rigorous, iterative process in which the decision analysis becomes more detailed as it proceeds. Intended for use in a group setting, CATALYST combines the broad, qualitative approach of senior managers with the detailed, quantitative approach of planners and analysts. It facilitates communication between these groups and helps produce analyses that all consider useful.

Scenarios and strategies

Scenarios and strategies are the building blocks of a CATALYST analysis (Figure 1), and the process explicitly recognizes their interdependence. It is obvious that planning scenarios shape the development of useful business strategies. Less obvious, but equally important, is that projected strategies shape the development of relevant scenarios; that is, the definition of the planning problem, and of potential strategies for dealing with it, determines what events are important to consider in developing scenarios.

A CATALYST scenario is a specified state of the world in which all planning factors relevant to the issue under consideration are quantified. Scenarios are designed to be internally consistent. In most cases, for example, it would be unrealistic to project an oil price shock and a simultaneous economic boom. Scenarios represent a useful planning approach in today's uncertain environment. Although the range of possible futures is too great to be covered by a single forecast, it is likely that the actual future will fall within the range defined by a good set of plausible scenarios. Moreover, scenarios illuminate key risks and opportunities and illustrate the need for flexibility.

There are many possible approaches to developing scenarios. CATALYST's unique contribution is that it provides a step-by-step process for building, within the context of specific strategies, a set of internally consistent scenarios that span a broad range of possible futures. The process screens out events that have little impact and combines the remaining events in a natural way. It explicitly considers the uncertainties associated with each scenario, as well as the likelihood and interdependence of events. The result is a comprehensive yet manageable set of scenarios—in most cases, 5 to 10—for use in evaluating utility business strategies.

A strategy produced with CATALYST consists of one or more initial actions and a set of subsequent actions that are contingent on future events—for example, new plant construction when demand reaches a certain level, or a switch in fuel if acid rain legislation is enacted. By construction, then, CATALYST strategies are flexible: they address and plan for potential changes in a utility's business situation. Moreover, they are comprehensive. They are not simply timetables for capacity expansion or the installation of new technologies. Instead, they encompass the entire range of utility options, including demand-side programs, service differentiation options, fuel and vendor contracts, market research, and institutional arrangements.

Given today's fluid, complex environment, CATALYST provides a way to achieve the planning flexibility utilities need. The process helps users confront uncertainties, articulate their assumptions and judgments, and consider all their options. Continually throughout the process, users are encouraged to examine the implications of their scenarios and explore ways to make their strategies more flexible.

Figure 1 CATALYST is a process for synthesizing key scenarios and developing flexible business strategies. It examines risks and opportunities caused by forces outside a utility, as well as those associated with specific utility actions and decisions. A matrix like the one shown here is used to evaluate the performance of each strategy under each scenario.

	Strategy 1: Start Coal Technology	Strategy 2: Make No Immediate Decision	Strategy 3: Contract For Short-Term Power
Scenario 1: Base Case	• Get Partner (1991)	• Continue to monitor options	• No action
Scenario 2: Economic Boom and High Gas Prices	• Accelerate DSM	• Start engineering for coal plant	• Same as strategy 2
Scenario 3: Economic Slump and Nominal Gas Prices	• Stop plant and DSM	• No action	• Accelerate marketing

Using CATALYST

CATALYST is an iterative process that involves increasingly detailed passes through five planning stages, each consisting of several steps (Figure 2). The passes raise new issues, point up specific needs for more information, analyze ways to refine strategies, and may even lead to entirely new alternatives. This iterative approach is especially useful for issues (like capacity planning) that are reexamined at regular intervals, since the results of one analysis can serve as the starting point for the next.

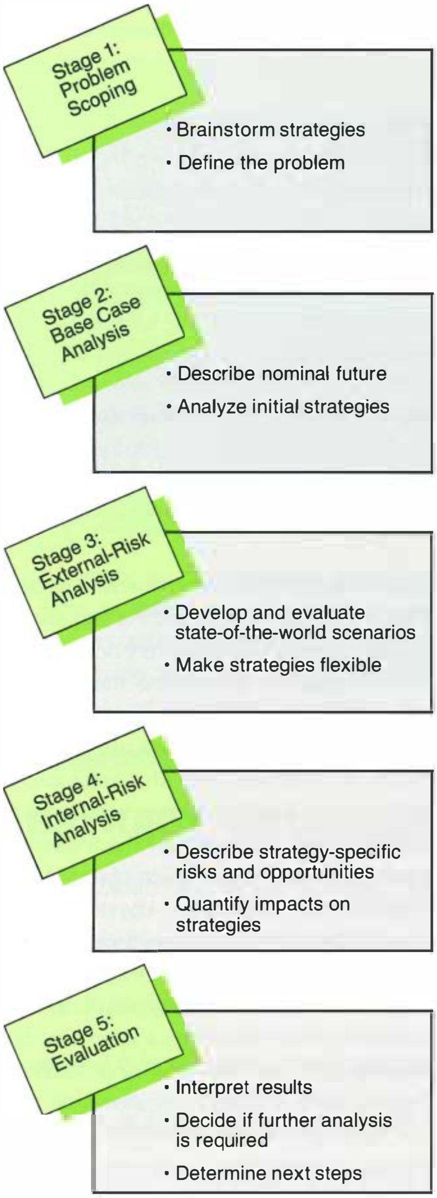
An initial CATALYST session brings together the managers who make business decisions and the analysts who generate information to support those decisions. Since both groups have an interest in the planning problem, both must be involved for the process to work well. In this session, which typically takes about two days, the group uses CATALYST to define and structure the problem and organize the available information.

The session begins with a quick, high-level pass through the process. The objectives of this preliminary pass are to familiarize the working group with CATALYST and to identify key issues early in the analysis. Next, the group proceeds through the five stages in more detail.

Stage 1, problem scoping, has three main objectives. The first is to brainstorm strategies and develop a broad set for analysis. The participants should be as comprehensive as possible in considering their options and should include future as well as current actions. The second objective is to define the decision problem precisely. What is the timeframe of the analysis, which specific current and future decisions will it address, and what assumptions will be made about company decisions outside the scope of the exercise? The answers to these questions indicate which of CATALYST's three analysis modes to use—immediate decision, contingency planning, or strategy review. The third objective is to choose the quantitative measure for evaluating strategies. In today's business environment, often it will not be appropriate to use the traditional criterion (present value of revenue requirements). Further, to adequately represent the interests of all the various stakeholders, it may be necessary to use more than one criterion.

Stage 2, base case analysis, has two main objectives: to define the nominal planning forecast, or future, and to quantify the performance of each strategy under that forecast. The participants quantify planning factors (e.g., demand growth rate, fuel prices) and articulate their assumptions about future events. In this stage key uncertainties surface—about planning factors, about events caused by forces

Figure 2 CATALYST, an iterative process with five stages, integrates the qualitative concerns of decision makers with the quantitative approach of planners and analysts to produce responsive, flexible business strategies.



outside the utility, and about events directly related to the utility's course of action. These are defined and categorized for later analysis.

Stage 3, external-risk analysis, focuses on events outside the utility's control, such as economic conditions and regulatory actions, and identifies how the utility can position itself to respond effectively to these events. The main objectives are to develop a manageable set of scenarios that captures the range of possible futures; to make each strategy flexible by specifying contingent actions in response to each scenario; and to evaluate strategy performance.

To create scenarios, the list of possible events from stage 2 is expanded, and events are combined by using a systematic process that takes account of their probabilities and important interdependencies. Then, using a scenario-strategy matrix, the planners examine each strategy under each scenario. As this analysis proceeds, strategies are expanded and refined, and new strategies are developed. The performance of each strategy is quantified for each of the scenarios, just as it was for the base case.

Stage 4, internal-risk analysis, focuses on technology- and strategy-specific risks and opportunities. These are called *internal* because they are associated with decisions or actions taken by the utility. For example, in a strategy calling for a demand-side management program, the customer participation rate is uncertain and represents a source of risk or opportunity. As was the case for external risks, internal risks are identified and combined into scenarios, contingency actions are formulated, and the performance of each revised strategy is quantified.

In stage 5, evaluation, the participants interpret the results of the analysis and decide what to do next. They examine the strategies' relative benefits and risks and characterize key issues and trade-offs. They also examine the robustness of the results, assessing their sensitivity to both scenario assumptions and probabilities. Finally, they decide whether to make another pass through the CATALYST process or to conclude the formal analysis and take action. Sometimes the analysis developed in the initial working session provides a sufficient basis for making business decisions. Often it reveals the need for more "homework"—for example, running a computer model to generate more precise numbers. In deciding how to proceed, the working group must weigh the costs of further analysis against the likelihood of developing an improved strategy and against its potential benefits.

This description suggests the rigorousness of the CATALYST process. By beginning at a qualitative, brainstorming level, CATALYST helps the participants move beyond their usual definitions of problems and goals, which may have been narrowed by past planning practices and business experiences. Then, as the analysis proceeds, CATALYST calls for the more detailed information needed to develop specific plans of action.

Because of its systematic treatment of scenarios and strategies, CATALYST minimizes the possibility of overlooking potentially important factors. Also, by structuring a problem so that issues are addressed in a logical sequence, CATALYST maximizes the usefulness of computer models and other planning tools. For example, costly computer runs are not made prematurely, before the problem has been adequately defined. Moreover, because a CATALYST analysis is logical and well documented, its results are easily communicated to the various stakeholders inside and outside the utility.

Case studies

CATALYST has been developed through a hands-on, case study approach with extensive utility participation. Eight case studies have been performed to date, covering a wide range of topics: capacity planning, strategic planning, fuel beneficiation, fuel contracting, environmental compliance, and the use of renewable resources (Table 1). For each, the EPRI project manager and analysts from the project contractors joined a team from the host utility for a two-day working session.

A case study at Duke Power, for example, addressed capacity planning. System modeling, the traditional approach, gives precise answers about when to build units. However, system models are dependent on the accuracy of the forecasts of load growth, fuel prices, and other planning factors that are used as input; by themselves, the models do not deal with uncertainty. Using CATALYST, Duke could examine the potential risks and opportunities associated with capacity expansion plans based on uncertain forecasts.

Table 1
CATALYST CASE STUDIES

Utility	Issue
Bonneville Power Administration	Strategic options
Duke Power	Corporate strategy on capacity planning
	Solid-waste-disposal contingency planning
Palo Alto Electric Utility	Corporate strategy on power pool options
Public Service of Indiana	Investment decision on environmental alternatives and life extension
San Diego Gas & Electric	Contingency planning for gas transportation strategy
TU Electric	Lignite-beneficiation investment decision
United Power Association	Corporate strategy on fuel supply planning

Another case study, at San Diego Gas & Electric, focused on natural gas transportation strategies. SDG&E used CATALYST to assess the advisability of investing in additional pipeline capacity, either to substitute for part of its current capacity or to supplement that capacity. Alternative strategies were considered under four scenarios to help SDG&E crystallize its thinking on this issue.

The case studies to date have demonstrated that CATALYST can address a broad spectrum of planning problems. This is important, given the growing diversity of the utility industry. Instead of supplying ready-made, generalized "correct" strategies, CATALYST helps a utility clarify its own goals and develop specific plans that support those goals. It forces planners to examine all the issues and risks associated with proposed actions, and to build flexibility into their strategies. Then, after initial strategy design, CATALYST provides a convenient, consistent way to monitor strategies over time and modify them as necessary.

Enhancement and transfer

CATALYST is available for application now. The project team is working on ways to promote and facilitate its use. A draft guidebook is available that explains the process and illustrates the formats used to generate information. Also, computer aids for using CATALYST are being considered. Expert system and relational database software could easily be implemented to enable users to generate and store the analysis information electronically.

EPRI also will sponsor regional CATALYST training courses. Successful implementation requires someone who thoroughly understands the process and can guide others through an analysis. The purpose of the courses, scheduled to begin late this year, is to train utility personnel to fill that role—to be in-house CATALYST experts and facilitators. EPRI is also assembling a team that utilities can hire for help in using the process. Finally EPRI is organizing a CATALYST users group.

CATALYST is a powerful tool whose fundamental purpose is to help utilities plan for uncertainty with confidence and flexibility. Such a business approach is essential as competition increases. As one utility case study participant concluded, "The industry needs to change its way of thinking about doing business. The kind of process we'll end up with *must* look a lot like CATALYST."

Environmental and Health Assessment

Power Plant Effects on Aquatic Life

by Jack Mattice, Environment Division

About half of EPRI's members (including 14 of the 20 largest utilities) depend in part on hydropower generation. Recent changes in the laws concerning the licensing and relicensing of hydropower plants, as well as in the U.S. Environmental Protection Agency (EPA) philosophy regarding the issuance of National Pollution Discharge Elimination System (NPDES) permits, have increased the importance of fish for the utility industry.

The Electric Consumer Protection Act (1986) stipulates that fish and wildlife concerns must be given equal consideration with other issues in licensing and relicensing. Although new major hydropower plant licensing has slowed, much small hydropower is still scheduled for development. Further, most of the large hydropower being developed involves pumped storage and thus is more important than the capacity indicates, because of the flexibility it allows in meeting peak loads. Relicensing appears to be an even more important industry issue. In the next decade, over 300 hydropower plants will be relicensed. Because effects on fish were given short shrift in the original licensing, the general consensus is that fish and wildlife issues will be the largest hurdle to relicensing.

Mitigation of most of the potential hydropower plant effects on fish will require water for maintaining fish and water quality, for bypass flows, and for filling fish ladders or lifts. It has been estimated that water losses (i.e., water lost for generation) could be around 10% or more at each hydropower plant. Edison Electric Institute estimates for costs to replace hydroelectric generation with coal or oil show that losses at this level for the 300 hydropower plants facing relicensing could cost between $53 million and $160 million per year. Federal hydropower plants are not subject to relicensing, but governing agencies are responsive to environmental pressures. The Bonneville Power Administration spends about $65 million a year to provide nonpower flows for salmon pro-

ABSTRACT *The effects of power plant operation on fish will be a critical focus of regulatory agencies during the licensing and relicensing of hydropower plants and the granting of National Pollution Discharge Elimination System permits to steam-electric power plants. In cooperation with utilities, academia, and state and federal research and regulatory groups, EPRI is developing tools to assess the effects of hydropower operation and mitigation on individual fish and to predict population responses on the basis of the effects on individuals.*

tection. Costs relative to generation are probably similar for other federal agencies (e.g., the Tennessee Valley Authority, the Army Corps of Engineers).

Capital expenses for mitigation also can be high. Northeast Utilities spent $13.5 million for a fish ladder and $1.1 million for a fish lift. Aeration, screening systems, and hatcheries can also cost millions of dollars apiece.

The EPA and state environmental agencies are changing their philosophy regarding NPDES permits. As a result of discharge reductions at industrial and municipal facilities, the quality of the nation's water bodies has improved. Against this background of more pristine conditions, utility industry activities are receiving increased scrutiny. Issues include impingement on intake screens, entrainment through the plant, and thermal and chemical effects of cooling-system and ash pond discharges. Nonpoint source releases, such as coal pile runoff, are also receiving attention. Although not now included in NPDES permits, surface water releases from underground storage are potentially another topic of regulatory concern.

Examples of the results of this change in philosophy are increasing. Virtually all the utilities in New Jersey are in the process of reevaluating potential intake and discharge impacts, and Region IV of the EPA is considering a similar strategy in the Southeast. In New York State, the Department of Environmental Conservation is considering whether to require protective screening for all power plants. A utility in Ohio has recently faced negotiations regarding the installation of cooling towers at a once-through power plant, and utilities elsewhere around the country (e.g., in Connecticut, New York, Virginia, and Illinois) are in the midst of similar negotiations. Mitigation measures, which can include intake screens, dechlorination, diffusers, cooling towers, and hatcheries for fish replacement, can cost millions of dollars.

From an industry perspective, one primary question is how to assess the effects of power generation and mitigation technologies on fish. The direct effects of power plant operation on individual fish (i.e., survival, growth, and reproduction) are critical to answering this question. The industry has made great strides toward assessing the direct effects of thermal plants on individual fish, but it has made less progress with respect to hydropower plants. One objective of a current EPRI project called SHAPE (steam hydropower aquatic population effects) is to develop methods for predicting the direct effects of hydropower generation on individual fish.

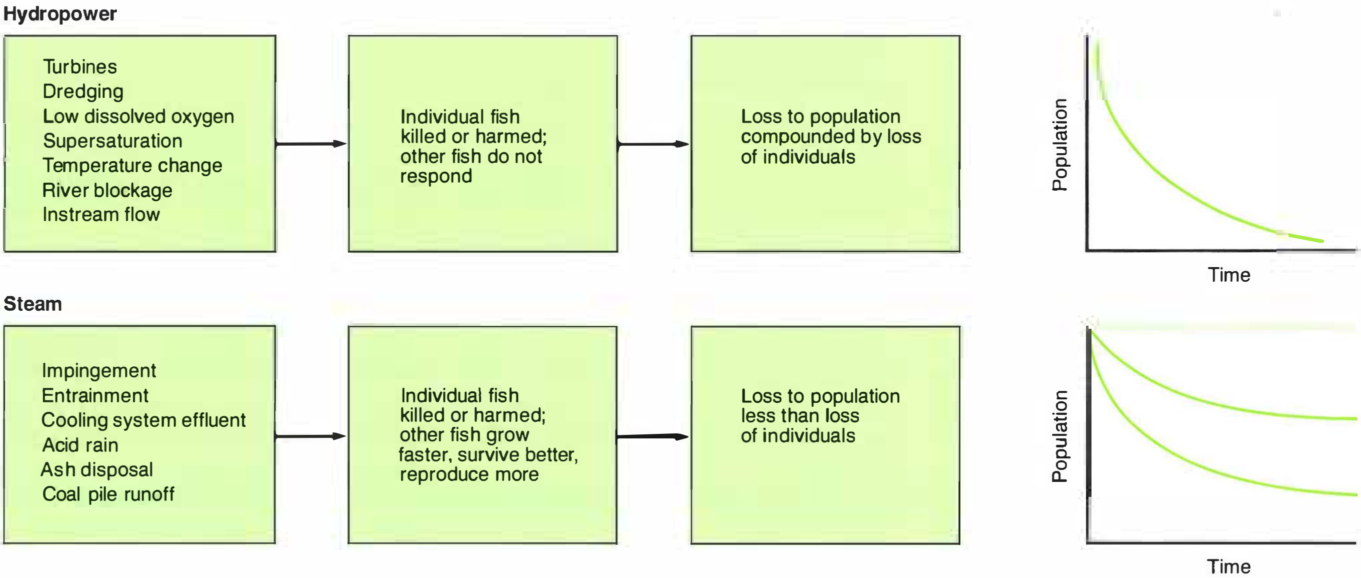
The prediction of direct effects, however, is not enough to make cost-effective decisions about mitigation. The long-term effects of hydropower plant operation on fish populations depend on the populations' response to the loss of individual fish. If the remaining fish do not respond, the losses will be compounded over multiple life cycles of the fish. The loss to the population will therefore be more than the yearly loss of individuals. This could result in the eventual loss of the fish from the water body (Figure 1). On the other hand, if the remaining fish grow faster, survive better, or reproduce more, the loss to the population will be less than the loss of individuals. Such responses, called compensatory, are universally recognized but have resisted predictive quantification. Using recently advanced methodologies, the SHAPE project seeks to identify and quantify compensatory mechanisms in order to develop simple indexes that predict compensatory capacity.

Direct effects

EPRI's Generation and Storage Division and Environment Division are funding studies to examine the use of lights and hammers (sound generators) to keep fish from passing through hydropower turbines. Hammers were shown not to repel fish. Fish responses to two types of light were species-specific and, in some cases, differed according to life stage. Site characteristics also can play a large role in determining whether a system will be successful in promoting fish bypass: mercury vapor lights roughly doubled the number of bypassed fish at one site but were ineffective at a second site. Studies will be completed late this year. The lessons learned will provide utilities a sound basis for designing optimal bypass enhancement systems at hydropower sites where they are needed.

In concert with Pacific Gas and Electric, Southern California Edison, and the California Department of Fish and Game, EPRI is cofunding instream flow studies at two PG&E hydropower plant sites. Instream flow refers to the amount of water that must be maintained in the stream below a dam to maintain a water use, in this case fishing. It is likely that PG&E will be required to increase flows above current levels. The rationale is that increased flows will increase the size of the fish population. However, none of the current models for predicting instream flow needs have been validated. Re-

Figure 1 Assessing the potential effects of power plants on fish requires measuring or predicting the number of fish, or the percentage of the population, killed or harmed. But population-level impacts depend on how the remaining or unharmed fish respond. The result can range from total loss of the population to population declines that are less severe, perhaps much less, than the individual effects. The choice of cost-effective mitigation strategies depends on being able to predict the response.



searchers have collected over three years of data on fish populations at the current flows. Beginning next year, similar data will be collected at the increased flows to see if any changes can be measured and if such changes are correctly predicted by the model recommended most frequently by the U.S. Fish and Wildlife Service.

Population effects

In 1987 EPRI initiated a two-part research program called COMPMECH (compensatory mechanisms in fish populations) to develop simple methods for predicting the compensatory capacity of fish populations. One part of this effort—the key species program, which is administered by Oak Ridge National Laboratory (ORNL)—is aimed at obtaining a more quantitative understanding of existing theory. ORNL has developed an innovative, individual-based model framework to guide the study of five to seven fish species. The primary research activity is measurement of reproduction, growth, and mortality of individual fish across the geographic range of the species or under circumstances where the size or structure of the test populations can be manipulated. The end product of the key species program will be a generalized model for predicting the direction and relative magnitude of fish species' response to site-specific impacts.

The generic model framework has been completed. The model includes all the processes and interactions that influence individual fish. The daily activities of each fish (e.g., feeding, growth) are simulated in detail. Each of these activities may be made a function of environmental conditions and of the individual's size or other biologically significant characteristics. This approach permits great flexibility in representing the differential effects of controlling processes on individuals of different age, size, and location. High-speed computers make it possible to simulate the activities of thousands of individuals, thereby allowing straightforward extrapolation from individual fish to a population.

A peer review workshop was held in February 1988 and hosted by Houston Lighting & Power. Participants, including some of the best industry, academic, and government fish population biologists in North America, endorsed the general approach and provided many specific suggestions that will enhance the model framework's credibility and ultimate usefulness to the utility industry.

The model framework forms the basis for developing species-specific models. These models are used to encourage utilities, government agencies, and academics with ongoing monitoring and/or research studies to join with EPRI in cooperative data collection efforts. The models are then used to design research plans, coordinate the efforts of the organizations involved, and integrate the results. Most of the EPRI funding is devoted to these coordination and integration efforts. Data collection is primarily sponsored (over $1 million in 1989) by the cooperating groups.

Three key species studies are already under way, and three others are under discussion. Winter flounder are being studied in cooperation with Northeast Utilities, the National Oceanographic and Atmospheric Administration (NOAA), the University of Rhode Island, the Rhode Island Department of Fisheries and Wildlife, and the National Marine Fisheries Service. Study sites are Niantic Bay (Connecticut) and Narragansett Bay (Rhode Island). Studies based on the research plan began early this year, and the species model has been completed. Results from a microcosm study funded by the NOAA at the University of Rhode Island were used to evaluate predictions of the winter flounder larval module. The model provided excellent fits to growth and survival of the larvae, but less accurate fits to the size distribution of the larvae at 28 days old. Reasons for the discrepancy are being examined.

A smallmouth bass research plan is being used to direct field studies at several Ontario lakes in cooperation with Ontario Hydro and the Ontario Ministry of Natural Resources. The species model will be completed in December. A search is on for other sites and potential participants. A research plan for the striped bass is in the final stages of preparation; the species model will be completed in November. So far, plans call for sites on the Sacramento–San Joaquin Delta (California) and the Hudson River (New York). Cooperating groups include the California Department of Fish and Game, the California Department of Water Resources, the California Water Resources Control Board, PG&E, the U.S. Fish and Wildlife Service, the U.S. Bureau of Reclamation, Consolidated Edison, the Hudson River Foundation, the New York Power Authority, and the New York Department of Environmental Conservation. Research staff are investigating the possibility of adding bay anchovy, yellow perch and/or walleye, and trout or salmon as key species.

The second part of the COMPMECH research program is a fellowship program administered by the Sport Fishing Institute. Its goal is to expand our conceptual understanding of compensatory processes and to provide a quality assurance check on the assumptions of the key species program. This research effort, conducted by PhD and MS students under the supervision of their faculty advisers, relies on an EPRI oversight group of academic and industry scientists. These scientists set topical goals for research, oversee the selection and conduct of the projects, and assist in the consolidation and integration of the data into the key species program predictive framework.

Through mid-1989, 14 fellowships were awarded. All of the fellowships are cofunded. Besides the universities involved (10), the cofunders include Houston Lighting & Power, Southern California Edison, PG&E, the National Marine Fisheries Service, the NOAA, the EPA, the Ontario Ministry of Natural Resources, the National Science Foundation, and the U.S. Fish and Wildlife Service. There is about one dollar in cofunding for every dollar of support from EPRI. As these projects are completed, the results will be integrated into the output of the key species program.

The SHAPE project is an integrated approach toward providing assessment tools for industry use in a regulatory framework. Besides the specific work on hydropower, the project will improve assessment tools currently being developed for toxic substances and for acid rain. Project output will be the *COMPMECH Newsletter*, EPRI reports and handbooks, workshops and other meeting presentations, and journal publications. In addition, the participation of several industry, academic, and government groups in this work, often on a daily basis, will increase acceptance of the models that are developed; improve communications between utilities and the academic and regulatory communities; and improve understanding of industry problems among the other groups.

Environmental Control Technology

Power Plant Water Management

by Wayne Micheletti, Generation and Storage Division

Next to fuel, water is perhaps the most valuable resource required for electric power generation. Water is used in almost every power plant process, including steam generation, systems cooling, maintenance cleaning, and solids transport (ash sluicing). For each use, the water quality and quantity requirements differ. Similarly, makeup water quality can vary significantly between plants. Therefore, managing plant water uses to meet process demands and increasingly stringent environmental limitations on wastewater discharges has become a complex problem for many utilities.

The introduction of the personal computer and the continuing improvements in PC memory and speed, however have enabled EPRI to develop water management codes based on research results and methods that were previously restricted to printed guidelines and mainframe computer codes (Table 1). These advancements in computer technology have improved EPRI's ability to produce generic water management tools that can be easily customized with site-specific data, and have increased the industry's ability to access and apply these codes to specialized problems with minimal training.

Since power plant water management must consider both water quantity (stream flow rates) and quality (stream compositions), EPRI has developed PC codes that address both issues. Two very good examples are WATERMAN and SEQUIL. As prerelease codes, both have been undergoing utility demonstration testing for over a year; they are scheduled for public release as production codes in early 1990 through the Electric Power Software Center (EPSC).

Preparing plant water balances

WATERMAN (for water management) is a menu-driven PC code that accesses FRAMEWORK II (an integrated database-spreadsheet software package) to develop complete water balances for an entire power plant or for individual plant processes. It consists of four basic sections that are used sequentially as needed: configuration design, water flow balance, chemistry mass balance, and economic eval-

ABSTRACT *Limited freshwater resources and more stringent environmental wastewater discharge regulations are increasing the importance of water management in power plant design and operation. However, variations in plant makeup water quality and in process needs make integrated water management approaches with multiple recycle/reuse streams complicated and difficult to evaluate. As a result, EPRI has developed several generic microcomputer codes that use site-specific plant data to simplify water balances and to analyze the associated aqueous chemistry for potential process problems.*

uation. Therefore, WATERMAN can model an existing or proposed design, calculate the associated water balance, predict stream compositions, and complete a cost estimate or an economic comparison of different options.

Some of WATERMAN's key features are:

▫ A question-and-answer, menu-driven format for data entry that requires no familiarity with FRAMEWORK II

▫ An internal database of typical plant values that enables a user to complete a simulation with temporary data until the actual plant or process data can be obtained

▫ Dual-level error checking to determine if user input is beyond a typical range (still acceptable for use in the simulation) or is beyond a possible range (not acceptable for use)

▫ An internal database of capital and operating costs that can be augmented by user input

▫ Multiple formats for output graphics with various levels of detail

Since March 1988, 15 utilities have received copies of the WATERMAN code for prerelease demonstration testing. As might be expected, differences in plant design and operation and in makeup water quality and availability mean that each utility has explored different ways of using the code.

One of the more extensive evaluations has been conducted by the Salt River Project (SRP) for the Coronado generating station. This station has two 350-MW(e) units with dry-bottom boilers, hot-side electrostatic precipitators, horizontal sulfur dioxide scrubbers, and mechanical draft cooling towers. Plant makeup water, supplied from two different well fields, is blended and lime-soda-softened before use. Plant process waters are segregated according to quality in three reservoirs (recoverable water, wastewater, and cooling-tower blowdown) for reuse throughout the plant via 15 recycle streams. However, the plant has no mechanical means of concentrating or purifying wastewater and is, therefore, limited in reducing makeup water demand through additional recycle/reuse approaches.

SRP used WATERMAN to develop a water balance for the existing water management system at Coronado station and to compare it with three alternatives under consideration:

▫ Sidestream softening of the main cooling system to increase the cycles of concentration, and secondary dewatering of scrubber sludge to reclaim water in the scrubber system

▫ Concentration of cooling-tower blowdown with a mechanical evaporator (brine concentrator) to recover high-quality water for use as boiler makeup

▫ Sidestream softening of the main cooling system, secondary dewatering of scrubber sludge, and concentration of all plant wastewaters with a mechanical evaporator

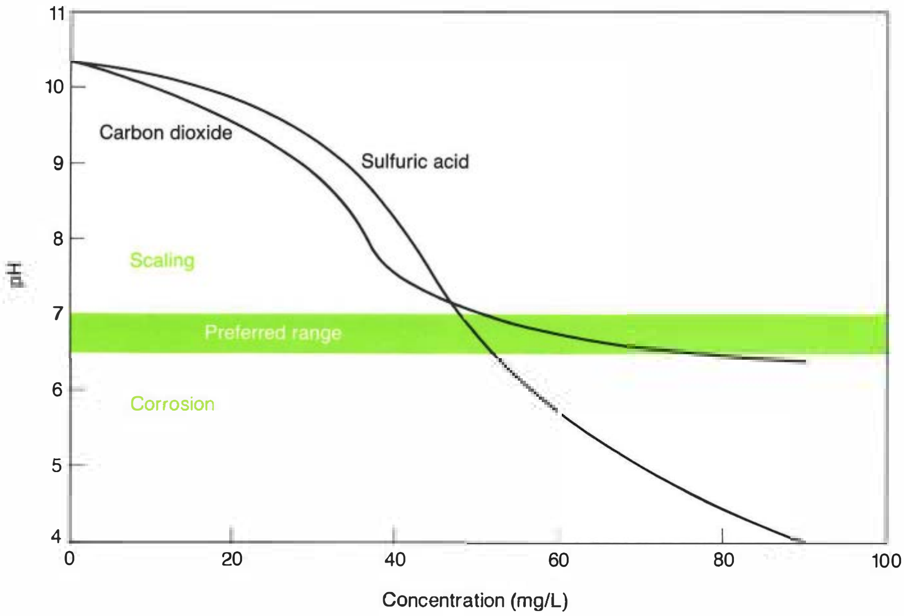
Although SRP's evaluation is not yet complete, the preliminary results generated with WATERMAN provided some interesting insights. For example, the first alternative actually increased total plant makeup water demand. Sidestream softening increases the cooling-system cycles of concentration by re-

Table 1
EPRI MICROCOMPUTER SOFTWARE FOR POWER PLANT WATER MANAGEMENT

		Minimum Requirements		
Code/Database	Description	Software	Hardware	Status*
COOLADD	Database of generic cooling-water additives	dBASE III (Ver. 1.1)	512K RAM, 10-MB hard disk	Production
DECHLOR	Dechlorination system design and evaluation code	MS DOS (Ver. 2.0)	256K RAM	Prerelease
FOULCOMP	Cooling-system chlorination evaluation code	MS DOS (Ver. 2.0)	256K RAM	Prerelease
SEQUIL	Aqueous inorganic chemical equilibrium code	MS DOS (Ver. 2.0)	384K RAM	Prerelease
SOFTEN	Lime-soda softener design and optimization code	MS DOS (Ver. 2.0)	512K RAM	Prerelease
WATERMAN	Integrated power plant water management code	FRAMEWORK II MS DOS (Ver. 2.1)	640K RAM, 10-MB hard disk	Prerelease

*Production software is available through the Electric Power Software Center; prerelease software is available through the EPRI project manager on a limited-distribution basis.

Figure 1 Using SEQUIL, utility personnel can evaluate calcium carbonate scale control by pH adjustment with sulfuric acid or carbon dioxide.



moving potential condenser scaling species (calcium and silica). Higher cycles of concentration mean reduced cooling-tower blowdown, which is a primary source of scrubber makeup. Since the increased filtrate from secondary scrubber sludge dewatering only partially compensated for this reduction, additional service water was required.

In contrast, the third option had a more beneficial impact on total plant water demand, but at higher capital and operating costs. SRP plans to perform further analyses to determine the costs and benefits of each option as part of its overall water conservation plan.

The WATERMAN utility demonstration program ended in June 1989. On the basis of evaluation forms completed by the participating utilities, final revisions and enhancements are being made to the code to prepare it for release through EPSC in early 1990. Judging from the demonstration utilities' experiences, it appears that WATERMAN will provide the industry with a quick and simple means of preparing complex water balances and evaluating recycle/reuse options.

Evaluating water chemistry

Water balances address only the quantity issue critical in power plant water management; the second essential aspect is proper control of water quality or chemistry. SEQUIL (for system equilibrium) is a code designed to evaluate the inorganic aqueous equilibrium chemistry of most power plant operations. (Certain systems have special requirements, such as boiler cycle chemistry or lime/limestone flue gas desulfurization reactions; EPRI has developed special PC codes for these systems, such as MULTEQ and FGDLIQEQ.)

SEQUIL, a revision and an enhancement of the earlier EPRI mainframe computer code DRIVER for cooling-water chemistry, considers the multiphase reactions of six cations (calcium, magnesium, sodium, potassium, ammonia, and iron), and six anions (chloride, carbonate, sulfate, nitrate, silica, and phosphate). Using thermodynamic constants corrected for system temperature and ionic strength, SEQUIL determines the liquid-phase ion pairing and the solid-phase precipitation potential or relative saturation of the solution. These results are very important in evaluating the impact of water quality on recycle/reuse options.

Because of scaling and corrosion in plant processes and lines, many water management systems are only partially successful. Scaling and corrosion are particularly prevalent in cooling systems operating at high cycles of concentration or in recycle lines and processes using poor-quality wastewaters from other systems (i.e., water with high total dissolved solids). Because SEQUIL calculates the relative saturation of major solid species, it predicts when water quality variations can lead to scaling. And since SEQUIL considers the influence of liquid-phase ion pairing, its predictions are more accurate than the traditional rules of thumb, which rely on only total species concentrations.

Prerelease demonstration testing of SEQUIL began in May 1987 and concluded in November 1988. During that time, two dozen utilities used SEQUIL in a number of ways. One interesting study conducted by Southern Company Services (SCS) and Georgia Power Co. (GPC) at Plant McDonough involved calcium carbonate scaling in a recycle line that returned fly ash pond overflow water for reuse within the plant.

Because calcium carbonate scaling is pH-dependent, a standard control approach is to lower the system pH through acid addition. Although sulfuric acid has commonly been used for pH adjustment, both SCS and GPC were concerned that accidental overfeeding of sulfuric acid would lead to excessive pH depressions and corrosive attack of the pipeline.

Although not in widespread use, carbon dioxide is one alternative to sulfuric acid that seems to be gaining in popularity. Using SEQUIL, SCS predicted the changes in pH and calcium carbonate relative saturation (scaling potential) for different dosages of either sulfuric acid or carbon dioxide. SEQUIL output (Figure 1) confirmed that carbon dioxide could successfully be used to control calcium carbonate scaling through pH adjustment and, unlike sulfuric acid, would not be subject to potential overfeed problems.

As a result, GPC installed a carbon dioxide addition system for the ash pond recycle line at Plant McDonough last spring. Preliminary field data indicate that calcium carbonate scaling in the line has abated; in fact, operation at the new lower pH actually appears to be removing some of the existing scale. This adjustment in water quality will prevent pipe valve malfunctions, potential blockage of ash hydrovactor nozzles, and possible replacement of several thousand feet of pipeline.

Because SEQUIL is a general multicomponent equilibrium code, it can be used to evaluate water quality control in several plant systems, including main condenser cooling, ash sluicing, and service water supply. When SEQUIL is used in conjunction with WATERMAN, a utility can quickly identify critical water management problems and assess possible solutions.

Additional supporting PC codes and databases

Although WATERMAN and SEQUIL are proving to be valuable tools for evaluating the related issues of flow and chemistry in overall plant water management, EPRI is continuing to develop other PC codes needed to address special issues of concern.

For instance, reported plant availability losses due to condenser biofouling problems average 3%, costing the industry $1.4 billion annually. Although utilities have traditionally used chlorine for biofouling control, environmental restrictions on chlorine use have limited its effectiveness. As a result, the industry is searching for ways to improve chlorination and maintain condenser performance without violating environmental discharge limits.

As part of a larger biofouling control research effort, EPRI is developing two codes that will help. FOULCOMP uses data from laboratory disinfection studies to predict optimum chlorine dosage rates, frequencies, and durations for biofouling control. DECHLOR, which is based on an earlier EPRI manual (CS-3748), provides step-by-step instructions for selecting and designing a dechlorination system to reduce the chlorine concentration in cooling-tower blowdown. Both these prerelease codes will be available for utility testing this year.

Other codes and databases include SOFTEN for optimizing lime-soda softener design and operation, and COOLADD for identifying cooling-water conditions and chemical additive usage at power plants across the country. COOLADD is available through EPSC; SOFTEN will be available in early 1990.

As the availability and use of the water management PC codes increase, EPRI will offer workshops and training seminars, hotline telephone support (usually through the software developer), and, in certain instances, on-site assistance with special applications. EPRI will also consider establishing users groups for one or more of the codes to improve industry use and to identify potential future revisions and upgrades. One enhancement already under review is the possibility of linking some or all of these codes through a PC workstation to improve the transfer of results and increase the access of users.

With increasing competition for good-quality water resources, more stringent environmental limits on wastewater discharges, and greater emphasis on plant performance and availability, the need for improved plant water management becomes more important. These EPRI PC codes will help the industry address that need in a timely and cost-effective manner.

CALENDAR

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

NOVEMBER

1–2
1989 Fuel Oil Utilization Workshop
Tampa, Florida
Contact: William Rovesti, (415) 855-2519

1–3
The Path to Biomass Commercialization
Orlando, Florida
Contact: Jonne Berning, (415) 855-2463

7–9
Seminar: Cool Storage
Birmingham, Alabama
Contact: Ron Wendland, (415) 855-8958

8–9
Seminar: Impacts of CFC Restrictions on Electric Utilities
Cambridge, Massachusetts
Contact: Tania Jemelian, (415) 855-2810

8–10
Conference: Geomagnetically Induced Currents
Burlingame, California
Contact: Ben Damsky, (415) 855-2385

9–10
Electromagnetic Transients Computer Program, Version 2.0: Features and Enhancements
Dallas, Texas
Contact: Mark Lauby, (415) 855-2304

9–10
Condenser Targeted Chlorination With Fixed Nozzles
Providence, Rhode Island
Contact: Winston Chow, (415) 855-2868

12–13
Static Electrification in Transformers
Monterey, California
Contact: Stanley Lindgren, (415) 855-2308

13–15
Conference: Marketing Electric Vans
Teaneck, New Jersey
Contact: Jim Janasik, (415) 855-2486

13–15
Electric Vehicles: Plugging Into the Future
Teaneck, New Jersey
Contact: Jim Janasik, (415) 855-2486

13–17
9th Battery and Electrochemical Contractors Conference
Washington, D.C.
Contact: Robert Swaroop, (415) 855-1097 or Glenn Cook, (415) 855-2797

14–15
Marketing Program Planning and Evaluation
Kansas City, Missouri
Contact: Tom Henneberger, (415) 855-2885

14–16
Conference: Plant Maintenance Technology
Houston, Texas
Contact: John Tsou, (415) 855-2220, or Dave Broske, (415) 855-8968

15–17
Static Electrification in Transformers
Princeton, New Jersey
Contact: Stan Lindgren, (415) 855-2308

27–December 1
Expo and Seminar: Meeting Customer Needs With Heat Pumps
Atlanta, Georgia
Contact: Mort Blatt, (415) 855-2457

30–December 1
Workshop: Ash Utilization
Atlanta, Georgia
Contact: Dean Golden, (415) 855-2516

DECEMBER

4–6
Advanced Computer Technology for the Power Industry
Scottsdale, Arizona
Contact: Murthy Divakaruni, (415) 855-2409

JANUARY 1990

17–18
Marketing Program Planning and Evaluation
Salt Lake City, Utah
Contact: Tom Henneberger, (415) 855-2885

FEBRUARY

7–8
Power Plant Water Management
Location to be determined
Contact: Wayne Micheletti, (415) 855-2469

21–23
EPRI Food Service Symposium
New Orleans, Louisiana
Contact: Karl Johnson, (415) 855-2183

MARCH

6–9
International Symposium: Performance Improvement, Retrofitting, and Repowering Fossil Fuel Power Plants
Washington, D.C.
Contact: Gary Poe, (415) 855-8969

20–23
EPRI–EPA Symposium: Transfer and Utilization of Particulate Control Technology
San Diego, California
Contact: Ramsay Chang, (415) 855-2535

21–23
2nd National Conference and Exhibition on Power Quality for End-Use Applications
Burlingame, California
Contact: Marek Samotyj, (415) 855-2980

MAY

1–3
1st International Syposium on Biological Processing of Coal
Orlando, Florida
Contact: Stanley Yunker, (415) 855-2815

8–11
1990 SO_2 Control Symposium
New Orleans, Louisiana
Contact: Paul Radcliffe, (415) 855-2720

JUNE

11–13
Applications of Power Production Simulation
Washington, D.C.
Contact: Mark Lauby, (415) 855-2304

JULY

29–August 3
International Conference: Indoor Air Quality and Climate
Toronto, Canada
Contact: Cary Young, (415) 855-2724

AUGUST

28–30
International Conference: Measuring Water-Borne Trace Substances
Baltimore, Maryland
Contact: Winston Chow, (415) 855-2868

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The Return of American Industry (page 4) was written by John Douglas, science writer, aided by three research managers of EPRI's Customer Systems Division.

Bob Jeffress, a senior project manager in the Industrial Program since 1986, came to EPRI after 13 years with the American Iron and Steel Institute, including 5 years as its director of technology, and 10 years with Armco Steel.

I. Leslie Harry became manager of the Industrial Program in early 1987 after seven years as a project manager. He was previously a consultant to Science Applications International, and before that he worked for seven years with the Department of Energy.

Ammi Amarnath, a project manager for process industry electrotechnology research, joined EPRI in January 1988. He formerly worked for seven years as a process engineer and supervisor for two manufacturers of process equipment, K-Sons Ltd. and Metito International. ■

Diagnosing Forest Stress (page 14) was written by Peggy Waldman, science writer, with technical input from **Robert Goldstein** of EPRI's Environment Division.

Goldstein, a subprogram manager in the Ecological Studies Program, is responsible for research on the effects of atmospheric deposition. He has been with EPRI since 1975, following more than five years as a systems ecologist at Oak Ridge National Laboratory. ■

New Paths to Methanol (page 24) was written by David Boutacoff, *Journal* feature writer, with assistance from two research managers of EPRI's Generation and Storage Division.

Conrad Kulik, a project manager in the Fuel Science Program, has been with EPRI since 1978, guiding research in many aspects of coal chemistry, behavior, and conversion. He formerly worked for eight years in process development at Conoco Coal Development and for three years as a process engineer at Consolidated Coal.

Linda Atherton, also a project manager in the Fuel Science Program, has worked in coal gasification and liquefaction—most recently with bioprocessing for cleaning up process residues—since she came to EPRI in 1974. She was previously a research scientist with Lockheed Missiles & Space and a process engineer with Brown & Root. ■

The Electromagnetic Transients Program: Designing for Disaster (page 32) was written by John Douglas, science writer, in cooperation with three staff members of EPRI's Electrical Systems Division.

Mark Lauby, a project manager in the Power System Planning and Operations Program, has been at EPRI since 1987, following eight years in transmission planning and system reliability assessment with the Mid-Continent Area Power Pool.

Neal Balu, manager of the Power System Planning and Operations Program since early 1988, came to EPRI in 1979 after seven years with Southern Company Services, where he headed the system dynamics section in the planning department. He was earlier on the faculty of the Indian Institute of Technology in Bombay for four years.

Rambabu Adapa joined EPRI in June 1989 as a project manager in Balu's program, where his special interests include transient analysis. He formerly worked for three years at McGraw-Edison Power Systems as a staff engineer in R&D and in planning studies for utilities. ■

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