Research Consortia Worldwide

ELECTRIC POWER RESEARCH INSTITUTE

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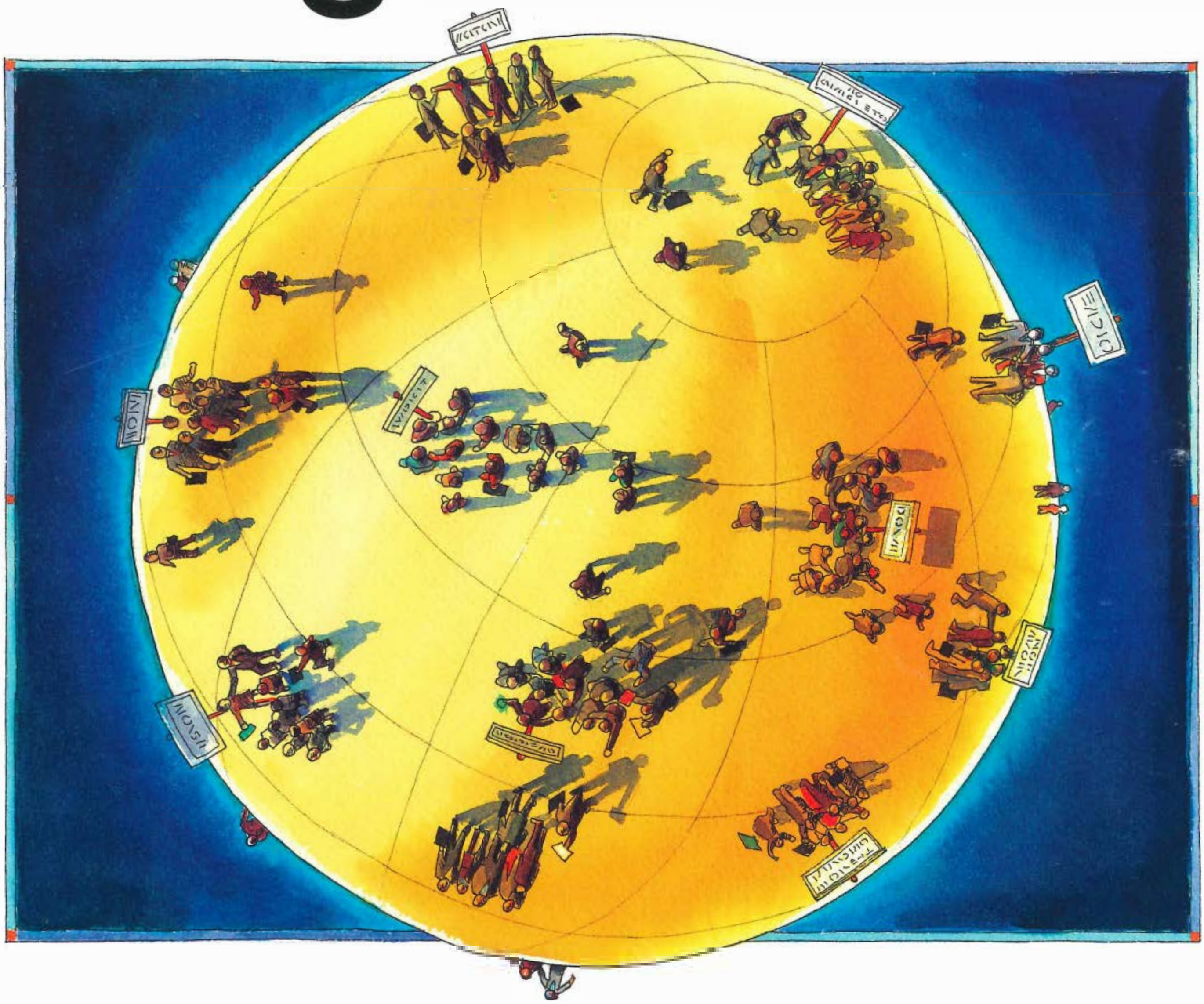

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Cover: By capitalizing on the advantages of pooled funds and expertise, consortia are becoming a powerful force in technology development around the globe.

Collaborative R&D in an Era of Heightened Competition

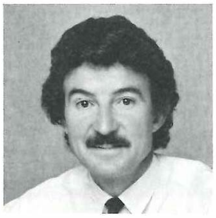
Until recently, nobody would have expected hard-nosed business leaders from high-technology firms to resort to a strategy of collaboration with potential competitors, especially in an era of aggressive competition. Collaboration is not usually associated with competitive advantage. However, the counter-intuitive has happened. Competitors are working with each other to develop generic understandings of, and capabilities in, advanced technologies. Each will later customize what they've learned according to their own business strategies and use it to develop competitive products.

Why does this approach make sense? Because the enormous resources required to develop new technology can deplete the coffers of even large individual firms, sometimes to the extent that they cannot afford the product development and the launch investments necessary to enter the market. Under these circumstances, many high-tech firms have concluded that they have little to lose and a lot to gain by collaborating in the early stages of R&D—the precompetitive portion of the innovation cycle.

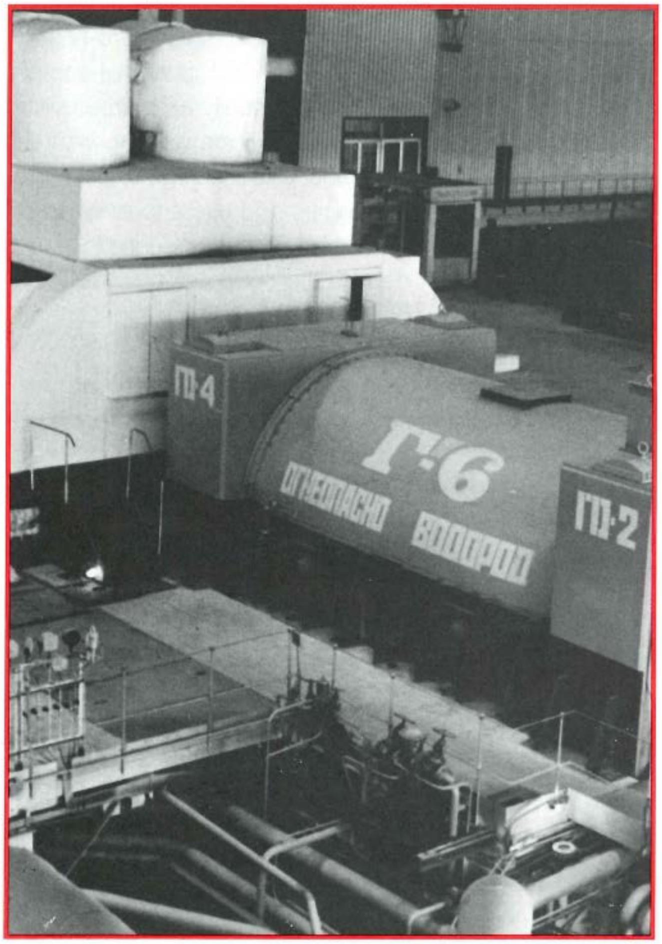
What does this have to do with the electric utility industry? First, this is a high-technology industry. The machinery and equipment it uses took decades and enormous investments to perfect, and there is no reason to expect this capital-intensiveness to change. Second, the industry is shifting from a largely monopolistic structure to an increasingly competitive one. Third, today's demands are stretching the capability and economic effectiveness of current equipment, increasing the importance of developing advanced technology.

There is a remarkable similarity between these circumstances and the ones that have led to the collaborative strategy embraced by traditionally competitive high-tech firms. Electric utilities share the enormous responsibility of providing reliable electricity service to a growing national economy in an environmentally acceptable manner; it makes sense for these companies to share the costs and risks of developing the basic technological capability that all will need for success in the marketplace. At EPRI, the industry's research arm, we share the challenge by helping our members lower costs, manage risks, and develop the technology of the future.

Who will succeed in this competitive environment? Since all of EPRI's members have access to the technology, the competitive edge will go to those who apply it most effectively. In any case, it is the ratepayer and society that will finally gain from the utility industry's commitment to the future and its support of the EPRI program: using scarce resources more productively and developing better ways to protect our environment will assuredly lead to an improved quality of life for us and for the generations to come.



Dominic Geraghty, Director
Office of Corporate and Strategic Planning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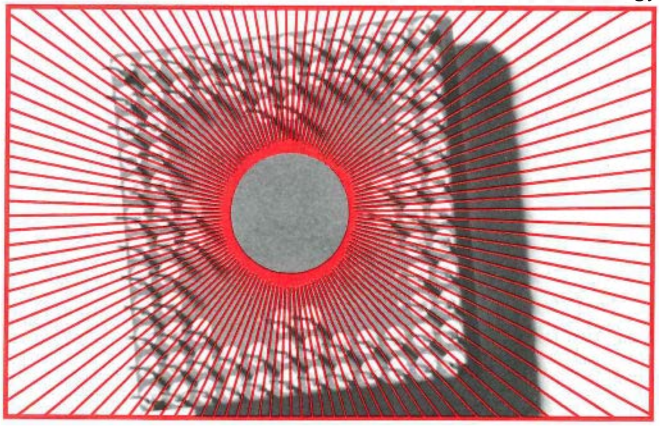
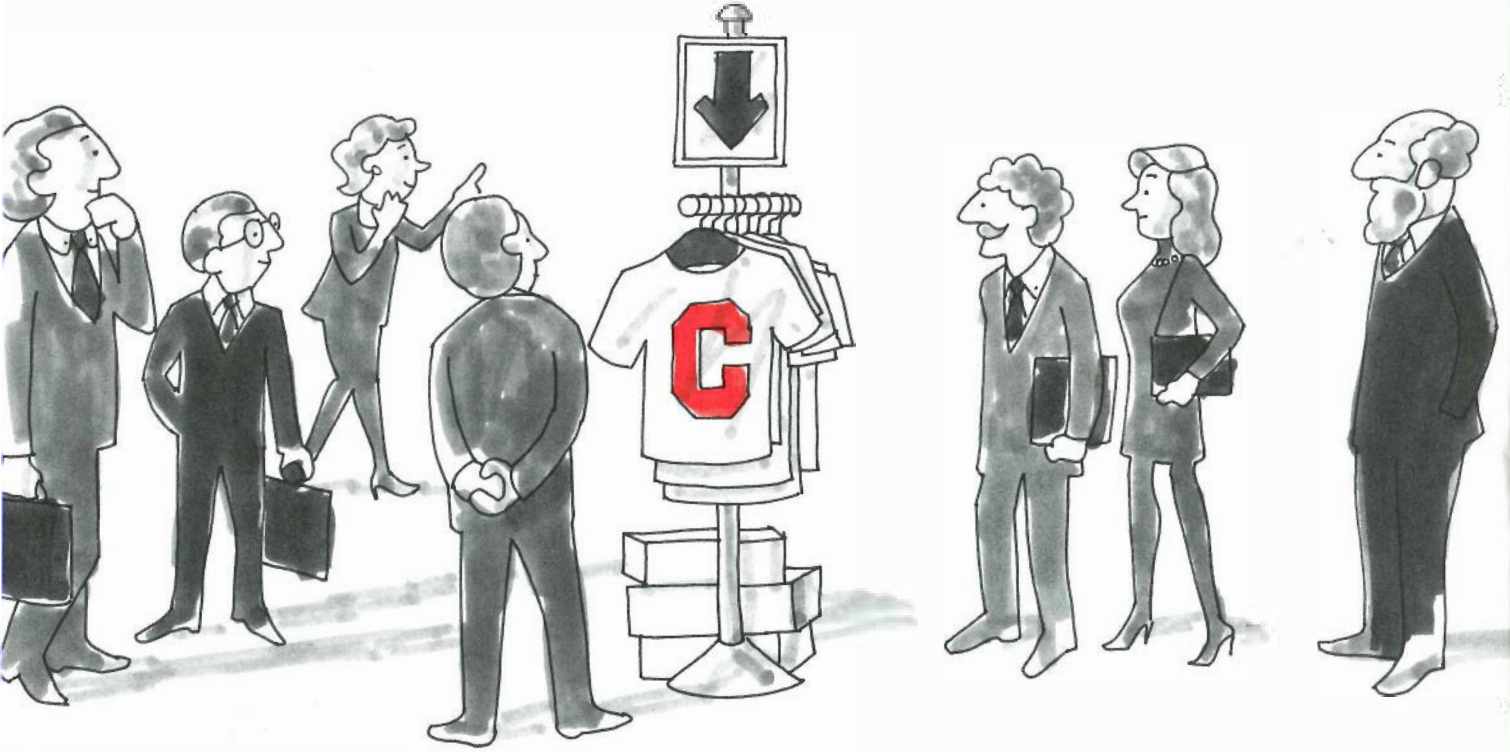




Consortia for R&D Advantage

Within the short lifetime of the Electric Power Research Institute, the idea of cooperative R&D has grown from novelty to necessity. When EPRI was incorporated, in 1972, its founders had to create—virtually from scratch—a new type of institutional approach to fulfilling the scientific and technological needs of the electric power industry. Inadvertently, they also established a model for many R&D consortia that have followed. Some of these, like EPRI, support a broad spectrum of ongoing research; others are designed to focus on a specific problem for a limited time. In both cases, the need for cooperation is growing rapidly as a variety of American industries face mounting global competition, escalating research costs, and rapidly increasing complexity of technology.

The press of international competition has now reached the very heart of America's technological enterprise. Many American companies have chosen short-term means of competing—by cutting costs rather than adopting a long-term strategy of investing in research. The proportion of U.S. gross national product devoted to nondefense R&D is currently lower than it was 20 years ago, and the percentage spent on R&D related directly to industrial growth is the smallest of all major industrialized nations. The strong effect this reduced commitment has had on innovation is reflected in recent patent data. In 1987, foreign inventors received nearly half of U.S. patents, and no American company was even among the top three recipients—all of which were Japanese companies.

"As competition and the pace of technological change accelerate, the importance of R&D and the advantages of a collaborative approach are magnified accordingly," says Dominic Geraghty, director of EPRI's Corporate and Strategic Planning Office. "A research consortium provides a mechanism for sharing cost and diversifying risk while offering

THE STORY IN BRIEF

How do you get the edge when business competition becomes really fierce? The surprising answer for the 1990s seems to be, cooperate with some of your competitors on research. By participating in R&D consortia, individual companies can share the cost of the early stages of R&D—giving them an advantage over international rivals—and still compete with each other through development of their own unique product lines. Pioneered in regulated American industries by groups such as EPRI, the consortium concept quickly swept the globe, finding particular favor in Japan. Now, with the recent relaxation of antitrust restrictions on R&D for nonregulated businesses, precompetitive cooperative research has blossomed in the United States, resulting in the formation of 115 consortia that represent over a thousand companies.

economies of scale and reducing unnecessary duplication of effort in addressing issues generic to the industry. It can also foster a creative environment for cross-fertilization of ideas through pooling human talent, which has become increasingly scarce in several key fields. EPRI not only has served as a pioneering model for such R&D consortia but continues to forge new paths in such areas as technology transfer and international cooperation."

Trends in collaboration

The origins of today's R&D consortia lie in the limited technical programs long conducted by industrial trade associations. These programs traditionally focused on such "housekeeping" functions as developing standards, conducting tests, and addressing safety issues. Early examples include the American Concrete Institute, formed in 1905, the American Iron and Steel Institute, 1908, and the American Petroleum Institute, 1919.

In contrast to the strictly noncompetitive activities of trade associations, research related directly to product development has traditionally been conducted by individual companies. Until recently, most of these companies had little incentive to cooperate in R&D. For decades, large American manufacturers were technologically self-sufficient and had little to fear from foreign competition. In addition, federal law restricted research activities between companies on much the same basis as it did other joint ventures; the restrictions included a threat of treble damages in antitrust suits.

Such antitrust considerations were of less concern, however, to companies in regulated industries, including electric utilities. In 1965, the Electric Research Council was organized to explore ways through which various segments of this industry could cooperate on R&D. A task force study adopted by the council in 1971 found that "present levels of R&D simply will not enable our industry to do what it must do to meet growing demands for electrical energy in ways environmentally acceptable."

Against this background, EPRI was founded in 1972. Within a year, the new Institute was undergoing a baptism by fire as the Arab oil embargo ushered in a period of energy crisis. EPRI funding grew rapidly as a variety of new programs were added to help electric utilities cope with fuel shortages and rising costs. In 1976, the Gas Research Institute (GRI) was formed to provide similar assistance to gas utilities.

In 1984, a third regulated industry—the Bell telephone system—underwent a drastic change that led to the formation of another major R&D consortium. As part of the court-mandated breakup of the national system into seven regional operating companies, Bell Communications Research (Bellcore) was formed to serve as a central technical resource. Taken together, Bellcore, EPRI, and GRI accounted for about 85% of total U.S. expenditures on collaborative industrial research in 1984.

A new breed

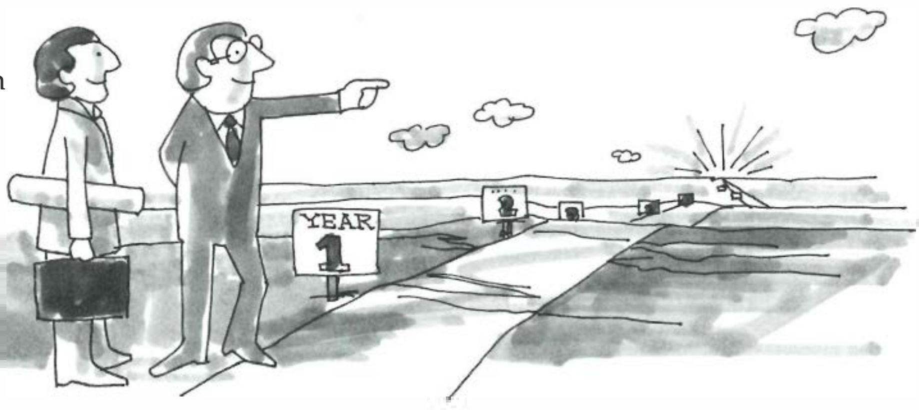
Collaborative R&D in nonregulated industries also received a boost in 1984 with passage of the National Cooperative Research Act. This law applied less stringent antitrust rules to R&D joint ventures and removed the threat of treble damages. Since its passage, some 115 research consortia have been formed, involving more than 1000 companies. And there is a possibility that antitrust rules will be liberalized further to allow joint product development, as permitted in some other countries.

Why would so many companies be willing to collaborate in today's tremendously competitive business environment? One reason is that in many industries, the traditional rivals are no longer the ones to beat—foreign competitors are often the greater threat in a largely international marketplace. In addition, most U.S. consortia go only so far in

Benefits of Consortia

Continuity

It often takes years of research to turn a good idea into a useful product. Consortia are better able to commit funding for the long haul and are less likely to scuttle a project just because budget is needed elsewhere.



their cooperative work. This new breed of consortium has mainly emphasized precompetitive research: individual companies pool their resources to ready a technology for commercialization, then proceed independently to develop competing products. While these products are based on the same technical knowledge, differences in management strategy, packaging, quality, marketing, and service still provide the consortium members a broad field on which to compete against each other. And because expensive research costs have been shared, all participants realize a preproduction cost advantage over nonconsortium competitors.

In their recent study of collaborative industrial R&D, Herbert Fusfeld and Carmela Haklisch of Rensselaer Polytechnic Institute identified several distinguishing features of the new consortia. They found that precompetitive research programs are usually tied to the companies' strategic plans for new business growth—such as the development of another generation of memory chips in the electronics industry. Also, participants include many of the large companies that were previously self-sufficient in technology development. Most of these companies are in high-technology industries and use the cooperative research ventures to supplement their own large R&D programs in order to secure a competitive advantage in the global marketplace. Finally, as the number of industry sectors involved in such research has increased, so have the scope of activity and the types of collaborative mechanisms used—mechanisms ranging from simple joint ventures to independent institutes and research corporations.

"At the heart of these new approaches to collective industrial research are fundamental changes in the patterns of R&D and its external relationships [for example, to corporate planning]," Fusfeld and Haklisch conclude. "Recently established groups have a more strategic agenda to support precompetitive activities."

Case studies

Two consortia in the electronics industry illustrate the potential of, and the problems facing, the new generation of collaborative R&D centers. One is the Microelectronics & Computer Technology Corporation (MCC), which began operation in 1983 just north of downtown Austin, Texas. Sponsored entirely by private funds, MCC was formed at the suggestion of William Norris, founder and chairman of Control Data Corporation, as an answer to Japanese collaborative work on a new generation of computers. The consortium is owned by 20 corporate shareholders, including not only such computer firms as Control Data, Digital Equipment Corporation, and Hewlett-Packard, but also several companies from other industries, such as Boeing, 3M, and Eastman Kodak. Work at MCC is broadly directed at a variety of issues related to computer design, software, and applications.

Some 25 miles south of MCC are the facilities of the Semiconductor Manufacturing Technology Initiative (Sematech), created in 1987 and sponsored equally by the federal government and private member companies. Sematech's mission—to develop advanced techniques for making integrated circuits—is both more narrowly focused and more manufacturing oriented than that of MCC. The consortium was formed at the behest of the Department of Defense, which had become concerned that increasing reliance on imported chips could pose a national security risk. Most of Sematech's 14 corporate sponsors, including IBM, are manufacturers of semiconductors or computers, and unlike MCC, the consortium has its own chip production facility.

In addition to their contrasting goals and organization, the two consortia have also followed very different approaches to daily operation. Although both institutions initially anticipated that about half their employees would be on loan from member companies for 2–4-year as-

Benefits of Consortia

Diversified Risk

R&D inevitably produces failures as well as successes. Consortia can pursue several approaches to a problem, knowing that at least one is likely to be a winner.

Benefits of Consortia

Financial Clout

Research is an expensive proposition. Cost sharing permits consortium members to pursue more and larger research projects than could be afforded by any single company. Results are equally available to all members.

signments, MCC reportedly found its members reluctant to make such a high commitment of technical expertise. Only about 15% of MCC's current employees are on loan. With its later start, Sematech tried to avoid this problem by interviewing candidates from several member companies for each job, thus creating an intramural rivalry for good positions. As a result, Sematech's work force is about evenly divided between employees on loan and those hired directly.

Another crucial difference is funding. MCC members are free to choose which of several dozen projects they want to support. The result has reportedly been a shift away from some of the consortium's ambitious original goals and a greater emphasis on short-term results. Sematech members contribute 1% of their annual semiconductor sales revenue, which is then matched by government funds. This arrangement has led to more financial security and a longer time horizon for research. With an annual budget of $200–250 million—more than three times as large as MCC's—Sematech has also been able to provide critical support to beleaguered manufacturers of semiconductor processing equipment.

It is still too early to assess the effect either consortium may have on America's competitiveness in electronics, but some progress is clearly evident. MCC has reported the transfer of more than 100 technologies to member companies—technologies ranging from an artificial intelligence software program to a new method for bonding chips to circuit boards. The first commercial product based on MCC technology was announced in 1987: the NCR Corporation's Design Advisor, an expert system for designing integrated circuits. Sematech recently completed construction of its state-of-the-art chip fabrication facility. Sematech members hope that, through work at this facility, they will be able by the early 1990s to gain access to new semiconductor processing technologies two or three years earlier than would otherwise have been possible.

In addition to establishing R&D consortia among themselves, many companies are seeking other ways to cooperate in research. One approach with broad social implications involves closer work with universities. In 1988, corporate research funding at U.S. universities totaled about $850 million, nearly three times the amount invested just seven years earlier. The mechanisms range from one-on-one industry/university R&D partnerships—essentially a contracting out of research formerly done in-house—to major campus-based centers with many corporate sponsors. Stanford University's Center for Integrated Systems, for example, began with donations of money to build a facility from some 20 companies and donations of equipment from 64 others.

Consortia around the globe

Rising international competition has, of course, deeply affected companies in other nations as well, prompting many of them to form new R&D consortia. In Japan, the latest consortia continue to follow a well-established practice of government-industry cooperation, long known as "Japan, Inc." In Europe, most large consortia involve companies from several countries and are aimed at increasing the technological competitiveness of the European Economic Community (EEC) vis-à-vis Japan and the United States. Another aim is to promulgate European technology standards in preparation for EEC market integration in 1992. Japan and several European countries have strong cultural traditions encouraging industrial cooperation, as well as less restrictive antitrust rules.

The key to collaboration among Japanese companies is the Ministry of International Trade and Industry (MITI). While providing only limited government funds, MITI has been able to organize and set policies for several research consortia, whose members include some of Japan's leading companies. The Very

Benefits of Consortia

Creative Synergy

Doing innovative work is the primary goal for consortia. Specialized resources, close interdisciplinary cooperation, and the free exchange of ideas leads to a whole that is greater than the sum of its parts.

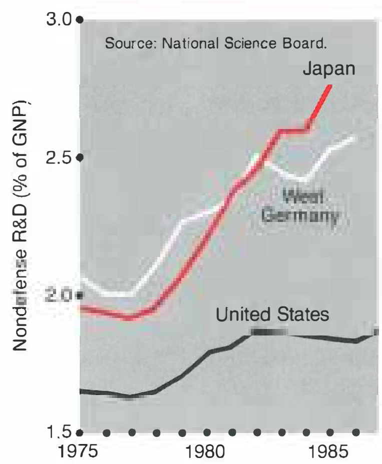
Large Scale Integration Project, which lasted just four years (1976–1979), helped catapult Japanese semiconductor manufacturers to dominance in circuit chip production. The Fifth-Generation Computer Project, which was organized in 1981 and inspired the formation of MCC in the United States, has been developing advanced computer hardware and software, including artificial intelligence. More recently, the Advanced Telecommunications Research Project was formed to provide an organizational umbrella for four related R&D consortia, and the Optical Technology Research Corporation has begun to develop advanced integrated circuits that make use of both electronic and optical elements.

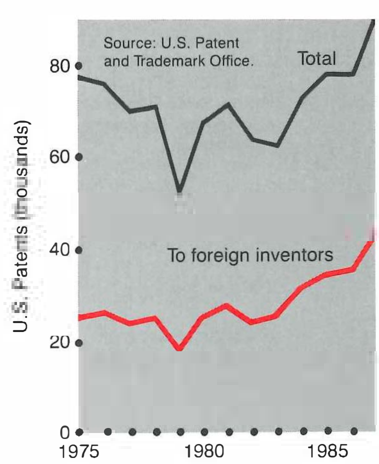
One of the world's most ambitious collaborative research efforts is the European Framework Program for R&D. In 1987, the EEC Commission approved $6.2 billion to provide five years' support under the program for multiple R&D consortia, some of which were already in existence at the time. One of these consortia, known as ESPRIT, has 62 member companies and five separate programs in information technology. Another, BRITE, is devoted to basic research related to industrial technologies, and RACE is developing advanced telecommunications with much higher message-carrying capacity.

Another major initiative is EUREKA, which provides a centralized funding mechanism for cooperation among European nations on a wide variety of research projects. Some 18 nations are taking part in the EUREKA program, which has so far committed $4.5 billion to 214 projects—ranging from development of

Numbers Going the Wrong Way

Short-term product goals and the debt-service costs of mergers and buyouts are taking their toll, just when innovation is becoming a worldwide competition. As a share of GNP, our nondefense R&D lags behind that of West Germany and Japan, and it isn't catching up. Also, nearly half of U.S. patents are going to inventors from other countries.





R&D Consortia Around the World

Name	Members	Purpose	Origin and Lifetime	Annual Funding
United States				
Electric Power Research Institute (EPRI)	691 electric utilities	Technologies for electricity generation, delivery, and use	1972, ongoing	$380 million (1990)
Gas Research Institute (GRI)	311 producers, pipelines, and distribution utilities	Technologies for gas supply, delivery, and use	1976, ongoing	$183 million (1990)
Semiconductor Research Corp. (SRC)	27 electronics manufacturers	Generic science underlying semiconductors	1982, ongoing	$35 million (1990)
Microelectronics & Computer Technology Corp. (MCC)	20 electronics, high-tech, and aerospace firms	Computer and information sciences and technologies	1983, ongoing	$65 million (1990)
Bell Communications Research (Bellcore)	7 regional firms of former Bell system	Compatible technology for nationwide telecommunications	1984, ongoing	$1.1 billion (1990)
Semiconductor Manufacturing Technology Initiative (Sematech)	14 semiconductor manufacturers, plus federal funding	Technology for integrated-circuit production	1987, ongoing	$200 million (1990)
Europe				
British Alvey Directorate (ALVEY)	60 organizations (universities, manufacturers, government agencies, and laboratories)	National capability in six information technology areas	1983, 5 years	$105 million (avg year)
European Strategic Program for Research in Information Technologies (ESPRIT)	62 information technology companies	European capability and standards in five information technology areas	1983, 10 years	$400 million (1990)
European Computer Research Center (ECRC)	Siemens, Bull, ICL	Logic programming techniques and prototype workstation	1984, ongoing	$1.24 billion (avg year)
European Research Cooperation Agency (EUREKA)	Commission of European Communities and firms from 18 nations	Facilitation of high-tech product development in Europe	1985, 3–5 years	$15 million (1986)

Name	Members	Purpose	Origin and Lifetime	Annual Funding
Europe (continued)				
EUREKA Project on High-Definition Television (HDTV)	Phillips, Thomson Group, Bosch, Thorn EMI	Development of 50-Hz-based HDTV system	5 years	$44 million (avg year)
Basic Research in Industrial Technologies for Europe (BRITE)	100 firms	Transnational R&D cooperation for European economic strength	1985, 5 years	$82 million (1990)
Research in Advanced Communications for Europe (RACE)	Commission of European Communities and over 100 organizations	Technology base for integrated broadband networks in Europe	1985, 10 years	$650 million (avg year)
Japan				
Central Research Institute of the Electric Power Industry (CRIEPI)	11 electric utilities	Technologies for electricity generation, delivery, use, and economy	1951, ongoing	$200 million (1989)
Very Large Scale Integration Project (VLSI)	Fujitsu, Hitachi, Mitsubishi, NEC, Toshiba	Development of integrated-circuit manufacturing equipment	1976, 4 years	$75 million (avg year)
Institute for New-Generation Computer Technology (ICOT)	8 computer firms and national government	Fifth generation computer system concept, architecture, and software	1981, 8–10 years	$50 million (avg year)
Advanced Telecommunications Research Project (ATR)	39 firms, including major electronics manufacturers	Planning and basic research in four telecommunications-related areas	1985, ongoing	Decided annually
Optical Technology Research Corp. (OTRC)	18 firms, including major electronics manufacturers	Development and production of second-generation optoelectronic integrated circuits	1986, 10 years	$6.7 million (avg year)
International Superconductivity Technology Center (ISTEC)	46 electronics, computer, and utility firms	Hot-superconductivity research, processing-technology development, and information exchange	1988, ongoing	$25 million (1989)

Sources: Bellcore and EPRI.

electronically controlled vehicle brakes to a European version of high-definition television.

Meanwhile, the U.S. government has also taken steps to increase cooperation between its own 700 laboratories and private companies. In particular, federal laboratories can now participate in mixed public-private R&D consortia. Federal laboratories can also form joint ventures with private companies through the Cooperative Research and Development Agreement, or CRADA, which enables the laboratories to provide facilities and labor to conduct research funded by the industrial partners.

Factors in success

Trying to institutionalize cooperation among a variety of people and organizations with different, and often competing, interests inevitably creates conflict. The success of a research consortium depends in large measure on how well these conflicts are resolved in favor of mutually agreeable goals.

Some of the key factors in making consortia successful were outlined in a 1987 presentation to The Conference Board by Alan Chynoweth, vice president for applied research of Bellcore and a member of MCC's board of directors and technical advisory board. (Chynoweth has this dual position because Bellcore is a member of MCC—what he calls "a consortium consorting with a consortium.") This type of research organization represents a "constant and age-old balancing act, that between cooperation and competition," he says. Specifically, success depends on balancing those factors that bring participants closer together ("centripetal forces") against those that promote disintegration ("centrifugal forces").

Among the centrifugal forces, Chynoweth identifies both personal attitudes (the "not invented here" syndrome) and, on the other hand, legal questions (such as the rights to intellectual property), nervousness over antitrust rules, and suspicions that some companies receive benefits out of proportion to their contribution (the "free ride" problem). Arrayed against these are the centripetal forces, which tend to be mainly economic: "Consortia enable fragmented industries to achieve some of the advantages of size. They allow to some degree the simulation of vertical integration further upstream into longer-range research, and perhaps more important, they allow the assembly of a critical mass of precious, scarce top-quality expertise."

To balance these forces successfully and produce useful research results, all R&D consortia have to wrestle with several generic issues. Clear goals are needed to reduce wasted effort, but divergent interests among the partners often make formulation of a mutually acceptable mission difficult. Continuity of funding is necessary for research that lasts many years. In addition, critical questions arise as to how much choice to give each of the partners in sponsoring favorite projects. Strong leadership is necessary to marshal independent researchers into an effective R&D team, but consortium managers must also have sufficient diplomatic skill to deal effectively with member executives. Most important of all, consortia must find effective ways to manage technology itself—from project inception to product transfer.

Management of technology

This theme has found particular resonance in the writing of Gerhard Mensch

Benefits of Consortia

Pooled Talent

Top people are scarce, but they tend to attract each other. Consortia can afford to build teams of talented individuals from a variety of disciplines and specialty areas to get the job done.

Reduced Duplication

Centralized planning and coordination ensure that research is done only once. Operating at the hub of a kind of information clearinghouse, consortium researchers can quickly find and pursue the critical path.

of the University of Berlin, who says a key factor in the management of technology is the "spaghetti effect." In other words, simply building up an inventory of new technologies in the hope that they will be adopted by manufacturers is like pushing on a wet noodle—it goes nowhere. "A well-established finding of innovation research," Mensch writes, is "that 'technology push' is an inferior way to introduce new technologies on the market; 'demand pull' is a major factor for successful innovation. If this demand is lacking, the rate of innovation is low."

The management of technology generally involves three separate activities. First, an R&D consortium must make sure that the research it undertakes will address its members' needs. Second, direct member involvement in research projects, at least in an advisory capacity, can help ensure continuous feedback and support. Finally, technology transfer to members at the end of a project will most likely have to take a variety of pathways if a product is to become commercially successful.

The challenge of meeting these requirements is now becoming more broadly appreciated. In their book *The New Alliance: America's R&D Consortia,* management consultants Dan Dimancescu and James Botkin argue that "overall, the subject of managing new technology . . . persists as a serious weakness of the R&D consortium movement. This offers an important clue, too, to the deeper weakness of the U.S. firms when it comes to competition against better managed Japanese firms."

A major part of the problem, they believe, is that member companies tend to underestimate the amount of effort and the investment—in both money and human resources—they must make if they are to benefit from technologies developed by a consortium. "In most cases management isn't prepared to tackle the assignment or hasn't anticipated the internal cost involved."

Dimancescu and Botkin conclude that better concepts of organization are needed to counter this tendency. "Knowledge is going to have to be treated as a strategic ingredient with information as its raw material; financial experts are going to have to learn the particularities of laboratory scientists; engineers are going to have to talk to nonengineers."

The EPRI connection

EPRI has had to face the challenges of mission, funding, leadership, and management of technology since its inception. Although the Institute's task sounds straightforward enough—to manage R&D for the benefit of the electric utilities and their customers—the practical difficulties of accomplishing this goal soon became apparent. First, the focus of EPRI's research was necessarily much broader than a single technology or discipline. The technical challenges of an increasingly complex and systems-oriented industry had been growing for decades before EPRI was founded; and EPRI's program would eventually encompass virtually every aspect of generating, delivering, and using electricity. There was a realization from the beginning that EPRI as an organization could bring important elements of efficiency, continuity, and perspective to the industry's research; but it was not clear how crucial these aspects would become until the environmental movement began to burgeon and the economy tightened up for the long term.

Over the years, such issues have regularly tested EPRI and its approach to R&D and found them to be both sound and flexible. EPRI has addressed the question of choices for new technology development—the demand pull from utilities—largely by way of an industry advisory structure. By sending members of their own technical staff to work with EPRI project managers in planning new research, utilities ensure from the outset that the resulting R&D projects will address their agreed-upon requirements.

However, utilities also have specific R&D priorities related to their own technical or financial situations. How can an organization like EPRI achieve a balance in its generic industry program that is also responsive to these specific priorities?

The Institute has found workable solutions to this problem, although the issue of individual versus industrywide needs will continue to be a challenge, as it will with any collaborative organization. One solution has been to survey EPRI members periodically to find out which areas of the R&D program they feel to be the most and least deserving of emphasis. This company-by-company perspective has resulted in effective fine-tuning of the R&D program as formulated with the representative advisory structure. Although EPRI members cannot at present restrict their funds to specific research projects, they do have clear opportunities to become closely involved with research of special interest, primarily by participating in demonstration programs and making early use of the resulting products. In addition, some EPRI benefits, such as the use of its test facilities, are available on a fee-for-service basis for solving individual member problems.

While a project is going on, utilities are encouraged to lend employees to EPRI to help manage technology development while gaining firsthand information about how a new technology can be applied. This formal program has provided an important opportunity for direct utility participation in several major EPRI projects. Over the years, some 179 such employees—representing 39 U.S. utilities and 10 foreign utilities—have come to EPRI.

At the completion of a research project, a variety of technology transfer mechanisms come into play. Personal communication is the most effective approach to achieving tech transfer, and such one-on-one contact is encouraged whenever practical. Other traditional methods include publications, workshops, and demonstrations at host utilities. But experience has made it clear that additional mechanisms—particularly vehicles that are demand oriented and user friendly—are needed to get technologies and information transferred effectively.

One new approach, now in the prototype stage, is EPRIGEMS, packages of interactive software on specific topics that can be used by utility personnel to solve problems as they arise at a plant or even on remote line locations. With these packages, which often integrate the results of a dozen or more EPRI research projects into a single expert system, practical assistance from EPRI can be as close as the nearest desktop computer. Another prototype, EPRINET, is a computer network that utility personnel will be able to use to sift quickly through the mass of EPRI research results to find the specific information they need and to quickly identify the key EPRI staff member to contact for further information. EPRINET even offers real-time computer conferences on topics of critical interest, such as electric and magnetic field research. For both EPRIGEMS and EPRINET, EPRI's goal is strategic: to use advanced technology to increase the effectiveness of communications with its member utilities. The latest in artificial intelligence frameworks and telecommunications technology enables member utilities to access the latest EPRI technology and incorporate it into their own planning and operations with the least delay and effort.

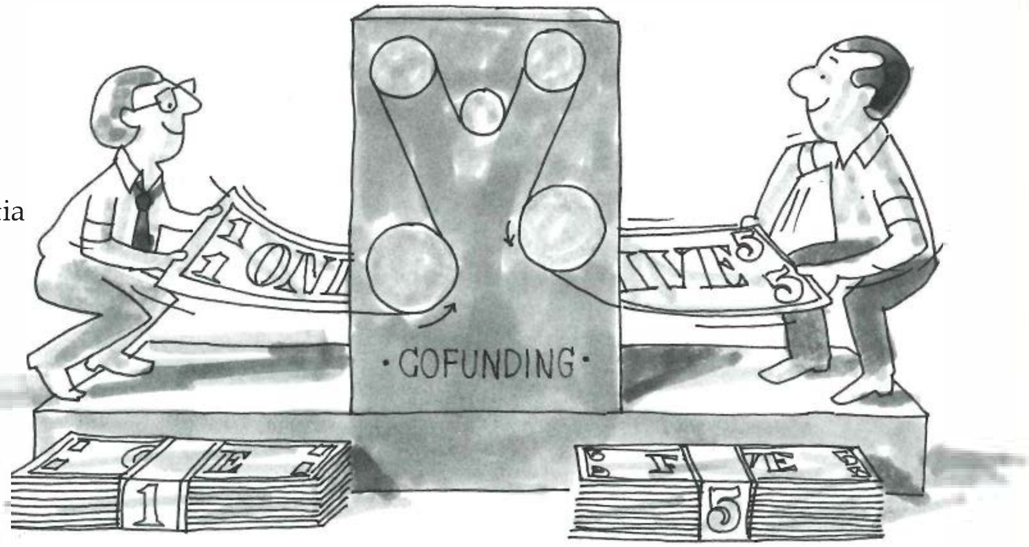
"EPRI has seen the need to go beyond technology transfer as it is usually understood, so we are adopting a broader concept of science and technology management," says Dom Geraghty. "In particular, we are paying more attention to defining the size of the market among our members for research results before we start a project. We are broadening the number of 'pathways' to the marketplace available to our R&D project managers. For example, in addition to the traditional 'dissemination' approach to tech transfer, we have set up an arm's-length venture fund to help commercialize technologies that are needed by utilities but that may not fit into the specific business plans of existing vendors. While we did not call them strategic business alliances then, we have sought such arrangements since EPRI's inception and continue to emphasize manufacturers' involvement in sharing costs and shepherding promising new technologies to market. Each of these activities, together with normal licensing arrangements, could expand and accelerate the availability of new technology for utilities, and any supplemental funds they generate will be plowed back into research."

Geraghty also points to EPRI's Benefits Assessment Program as an example of how consortia can become more accountable to their members. In this ongoing program, EPRI works with individual utilities as they calculate the dollar value of having introduced EPRI products onto their systems. In purely economic terms, the benefit-cost ratio for utility participants has averaged three or four to one. In addition, however, the program has revealed numerous unquantifiable benefits that many utilities have regarded as even more important. These benefits include the enhanced ability of EPRI members to keep up with rapidly changing technology and the availability of objective, up-to-date research results that can be used in public forums dealing with such policy issues as acid rain and nuclear safety. Partici-

Benefits of Consortia

Funding Leverage

With the ability to do unique R&D on a large scale, consortia carry the power to attract additional support and funding from government, related industries, or other interested groups.



pants in the benefits assessment also reported that this effort "opened some eyes" in their utilities about missed opportunities for applying new technology.

A bright future

In addition to staying well informed on their members' needs, it is important that consortia keep a close eye on outside issues and economic forces that affect their industry—to anticipate and have enough flexibility to adapt to the demands of the time. With its beginnings largely in the supply-side concerns of the early 1970s energy crises, EPRI has broadened its focus significantly over the years with the tremendous growth of environmental concern and, most recently, the rise of global competition, which has heightened the importance of industrial electrotechnology. Other changes occur more suddenly, as in the case of EPRI's emergency response on behalf of the utility industry to the accident at Three Mile Island. Member utilities and their customers benefit not only from the long-established lines of research but also from the flexibility that comes with having a pool of talent and information available to respond to changing needs.

One of the most important changes for some of the largest U.S. consortia in the coming years is likely to be increased cooperation with research organizations abroad. Although many consortia in this country were started to help American companies keep up with foreign competitors, there will be increased pressure for them to cooperate more with international groups as technology becomes even more complex and expensive. Again EPRI has been among the leading-edge models for other consortia, in this case because of its extensive cooperative activities with foreign utilities and research groups. One leading example of this activity is EPRI's work on advanced nuclear reactors with passive safety features, which now has support from several nations.

"EPRI is still unique in several respects; over its first 17 years, it has already had to wrestle with some difficult problems that other consortia are just beginning to face," says Dom Geraghty. "Probably the most important factor is sheer size. With more than 700 members—more than twice the number belonging to the next largest consortium—we *have* to be more innovative in such areas as technology transfer to our member utilities. Also, many of the scientific and technological challenges facing the utility industry already have global implications, including environmental protection, nuclear safety, and the need for greater energy efficiency. That's why EPRI must become a leader in seeking international cooperation in research in these areas and trading our own know-how prudently for access to foreign technology."

Beyond the immediate advantages a consortium offers its members, in terms of competitiveness and cost sharing, Geraghty also sees R&D consortia as providing benefits to the public at large. "EPRI does more than just provide utilities with new gadgets; it enables them to partake in an important industry commitment to discharge their social responsibilities in a cost-effective manner. That's why our industry has emerged as a leader in understanding environmental issues and developing advanced technologies to protect our environment. The same is likely to be true for other R&D consortia as their programs broaden and they take on the challenge of increasing the nation's competitiveness in global markets. Cooperation in research is now a necessity in many industries, which means a bright future for consortia like ours." ■

This article was written by John Douglas, science writer. Background information was provided by Dominic Geraghty, Office of Corporate and Strategic Planning.

In recent decades the pace of development in computers and telecommunications has become so swift, and the applications front so broad, that close observers now regard the information era as an almost undeflectable force for the future, possibly rivaling the Industrial Revolution in its eventual social impact. Certainly the rate of generational advance in information technology has been unprecedented. Product development cycles for computers are now measured in months—typically 24 to 36—and just keeping up has become a major challenge for most organizations. U.S. firms now devote about 40% of all equipment expenditures to information-related technology. And astute firms in the information technology business see the need to keep several generations of machines in the R&D pipeline to ensure enough flexibility for survival.

But just where is our society going with all of this technology? How and where are we going to use all of this new computing power? Will it, in fact, transform our industries and our economy, the structure of our organizations, the very nature of work and the workplace, our educational and creative pursuits? Exploring this phenomenal growth and its potential impact on the business world was the basic challenge set before the 60 participants at the 1989 EPRI Summer Seminar, entitled "Implications of Future Advances in Communication and Information Technology." Six speakers catalyzed two days of wide-ranging discussion among members of EPRI's Advisory Council and Board of Directors and their guests—prominent leaders from academia, government, and industry.

Engine of the revolution

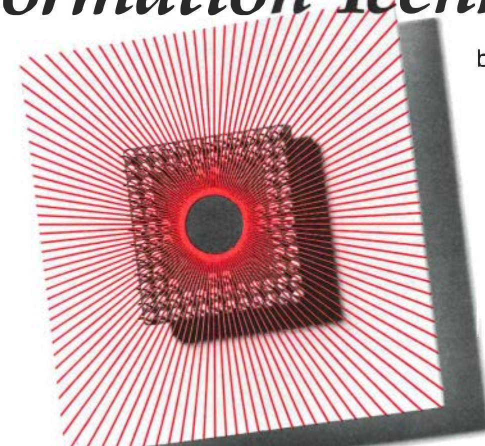
John Armstrong, vice president for science and technology at IBM, kicked off the meeting with a fast-paced overview of the outlook for computers and information technology. "Miniaturization," he emphasized, "is one of the basic messages for the future. It is the engine of the computer revolution. We have been miniaturizing components over the last two decades at a compound rate of 15–30% per year. And I'm confident that this engine will be just as strong for another 10 to 20 years and probably beyond. Eventually, we will see billions of bytes on a chip the size of your fingernail."

As a result of this basic compression in scale, Armstrong sees compact processors as powerful as today's mainframes emerging in the next 10 to 15 years. "No doubt about it. And by that time we will also have the ability to build computer parts atom by atom or atomic layer by atomic layer," he said. Emphasizing just how far we have come technologically, he reminded everyone that when he was in high school it was considered axiomatic that no one would ever see an atom, let alone build parts with them. To lay that idea to rest, he showed the seminar participants a photograph of individual atoms.

Looking a bit further out at the evolu-

The Power of Information Technology

by Brent Barker



MAKING CONNECT

tion of the computer, Armstrong envisions the growing inclusion of optical technology, the eventual use of superconducting circuits, and storage capacities almost beyond belief. "Light will play as large a role in future computers as it does in today's telecommunications, with the first inroads being optical fibers for interconnecting subsystems. But superconductivity? Probably not before 2010. It's not until power densities in integrated circuit wires get above 10 million amps per cubic centimeter—ten to a hundred times higher than possible today—that the absolute advantages of superconductivity will be important. As for storage, sometime in the next few decades we will begin to approach the kinds of information storage capabilities you get in living creatures."

Does he mean that we will someday see biologically grown computers? Pressed to speculate by several participants, Armstrong added, "Like a lot of things, the popular notion of 'biochips' has a nugget of real promise and a lot of hype. We are

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THE STORY IN BRIEF

Speakers at the most recent EPRI Summer Seminar see dramatic changes coming from advances in information technology. On the hardware side, miniaturization of components will continue to drive innovation. Much of the tremendous power of twenty-first-century personal computers—greater than that of today's mainframes—will be invested in more natural man-machine interface capabilities, including practical speech, handwriting, and image recognition. But more important will be the effect information technology will have on how we do business. Manufacturers' instant access to retail sales data will give new meaning to demand-driven production, leading to greater choice and customization of products. And innovative use of "corporate connectivity" is likely to change the shape of business management across the board, from administrative procedures to teleconferencing to organizational hierarchy.

Armstrong

"Miniaturization is the engine of the computer revolution. We have been miniaturizing components over the last two decades at a compound rate of 15–30% per year. And I'm confident that this engine will be just as strong for another 10 to 20 years and probably beyond. Eventually, we will see billions of bytes on a chip the size of your fingernail."

already beginning to see the integration of biologically sensitive probes and silicon microprocessors on the same chip. But that's a very different thing—I'm extraordinarily skeptical about computers of the future being grown out of protein."

Nevertheless, Armstrong's point is that storage capacities will continue to progress toward the biological level of billions and eventually tens of billions of bytes per square inch, and that computing power, by today's standards, is going to go out of sight. But what is not evident is where all this computing power will be used. What will it mean when virtually everyone has the equivalent of a mainframe or two at their fingertips? The answer from Armstrong's point of view is to use the power to get rid of the fingertips—that is, to move toward faster, more natural modes of interaction with a computer than the byte-by-byte tapping of today's keyboard.

"The world is not going to drown in excess computer power," said Armstrong. "This additional power is going to move out into improving and diversifying the computer's interaction with the user. We will be moving toward the recognition of handwriting, speech, and images, which all require data rates and processing power that are many orders of magnitude greater than typed instructions.

"Coming soon, as a result, you will have direct manipulation of PC displays, where, for example, you can write a sum sign on the screen over a column of numbers and get an answer. In 5 to 10 years, you will be able to write on or dictate to an electronic notebook, where your notes and instructions will be turned immediately into readable text. And full speech recognition is around the corner. Right now it is possible—in experimental systems—to get up to 97% accuracy using 20,000-word vocabularies. But this is, of course, very stilted, disconnected speech," Armstrong said, making his point by drawing a disconcertingly long pause after each word. "The fully connected speech of normal conversation is still beyond today's technology—the algorithms are just too complex. But eventually, we will be talking very naturally to the computer."

What Armstrong is suggesting is that much of the advance in computer power will go into making the computer not only faster and friendlier, more powerful and versatile, but also more transparent to the user. If so, this should help make computers more acceptable partners in the work world and in the home; and by helping to bypass today's constraints of computer literacy, it would also, arguably, speed and deepen their penetration into society.

As the forum turned from hardware developments to the broader implications of information technology, Armstrong reminded the participants that "we are still very early in the spread of computers into our lives and into our culture. As an industry, we are perhaps about where the electric power industry was in 1910."

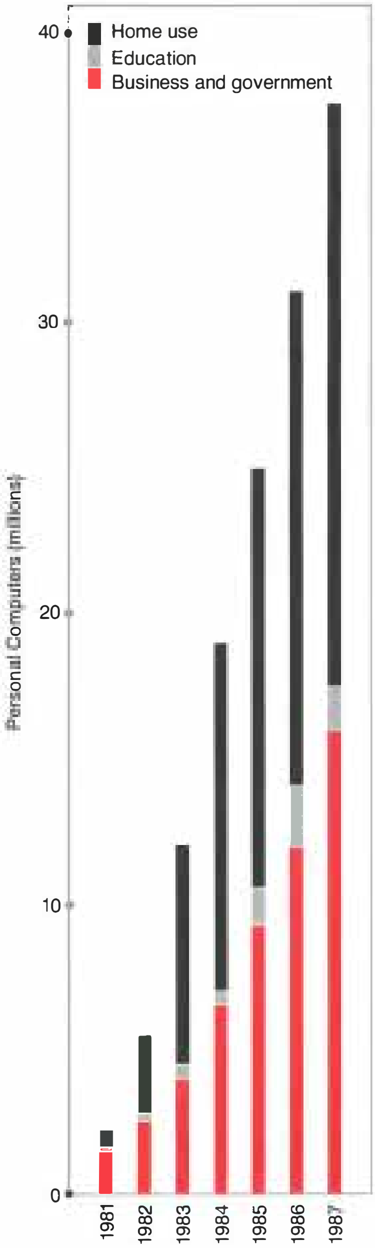
Armstrong was referring to the time when electric power was on the threshold of a second and fundamentally different phase in its development. Before 1910, it was used primarily as a substitute for such things as gas lights and large steam boilers. After World War I, however, it began to transform industry in new and unpredictable ways. Small unit drives and the flexible electric cord combined to open up the factory floor to total reorganization and surging productivity. And after World War II, still a third door was opened by the convergence of new control technologies and electronics. Armstrong's point is that no one in 1910 could see very far beyond the substitution phase. It was difficult to conceive that this new technology—electricity—would allow you to actually rethink the basic process of production.

Henry Kelly, senior associate at the Office of Technology Assessment, picked up Armstrong's thread. "Trying to forecast the implications of electricity in 1910, we would have missed much of the modern world—most consumer applications, industrial processes, air conditioning and the opening of the South, electronics, automation, and computers, to name a few. In fact, the entire information revolution is itself an outgrowth of the ability to manipulate electricity. No one could have envisioned the ability to move, store, and manipulate information in this manner just 80 years ago, or that moving information would become the dominant form of work in the U.S. today."

As was the case with electricity, Kelly sees the information revolution proceeding in two stages. The first involves various forms and types of direct substitution. The second, which we are just now entering, involves "deeper adjustments, not readily understood, where you rethink the product entirely and how you go about making it. It is in this phase that the unexpected, indirect effects begin to

Personal Computers Take Off

Miniaturization and improvements in user-friendliness have increased personal computer sales dramatically and broadened the base of users from the technical expert to the common man. In particular, the burgeoning of home use implies that personal computers are being truly assimilated by society as a part of everyday life.



Source: Statistical Abstract of the United States

emerge and eventually dominate." In Kelly's view, it will take a generation or more for these deeper adjustments to work their way through our institutions.

"We are still playing catch up. With the scaling in integrated circuits, the cost of maneuvering information dropped by a factor of 1000 in the last 15 to 20 years, and our economy is still trying to adjust to that reality. And we see the cost dropping by another factor of 1000 in the next 20 years. Ultimately this will cause very profound changes in the nature of our economic institutions—in their size and structure, in the way they contract with one another, in the psychology of management, and in the relationships to the market."

Kelly remarked on how some of these adjustments have already begun to play out. Looking at the manufacturing system, he noted that firms are getting somewhat smaller—the number of people per establishment peaked in 1967 and has been going down ever since. He also noted that the preponderance of new jobs created in this country are now structured around the handling and management of information. And in terms of production inputs, the mix is changing from the physical to the transactional. Since the mid-1970s, manufacturers have been using less materials and energy and more services. The result in Kelly's view is an economic trend of providing "more value added per pound of stuff."

According to Kelly, one likely clue to the still-deeper adjustments looming ahead can be found in the ability of information technology to dramatically increase customer choice—and, by putting the customer firmly in the driver's seat, to essentially alter the logic of production. Evidence can be found in the food industry. In Kelly's view, it's no coincidence that the average supermarket in the United States now carries some 20,000 products, up from around 3000 in 1948. The basic reason is not so much greater floor space as tighter inventory control and tighter linkages throughout the entire food-processing chain.

"You need to look no further than your ordinary frozen pizza," said Kelly, "to see how much information technology is now embedded in food products. When the bar code on the package slides across the scanner, not only is the checkout speeded up, but the information is captured, automatically triggering inventory control, product reordering, and a host of marketing, communication, and delivery systems upstream. It can go all the way back. It's hard to find a farm these days that doesn't have a computer somewhere in a backroom tied into a network. For the supermarket, it allows smaller batching of products; for the consumer, ever-expanding choice."

Taken to an extreme—and it looks like we might get there someday—it will be the point of consumer purchase that triggers the entire production train. Dupont, said Kelly, did a study that revealed it took 66 weeks for one of their fibers to work its way through the system to end up on a retail shelf in the form of a bathing suit. "They and others plan to do what the grocery stores have done. Instead of enormous inventories of products moving sluggishly through the system, the purchase of a bathing suit will someday automatically register in production systems up the line—apparel to textile to chemical. There will be smaller production batches and wider variety."

What Kelly is suggesting is a reorientation of manufacturing, a sort of paradigm cartwheel where the information revolution ends up turning the Industrial Revolution on its head. It's not that the factory system is thrown out. It's that the supply dominance of the last two centuries—the focus on achieving efficiencies through the standardization of jobs and products, through mass production and mass marketing—slowly yields the factory floor to the demand side.

"The first revolution, the Industrial Revolution," said Kelly, "took people from producing their own things with their own hands and put them into factories where the dominant form of work was an assembly line. They gave up precisely tailored products to create large quantities of cheap, uniform products. In the second revolution, the information revolution, where the dominant form of work is information, we will now be able to get individual tailoring and productivity at the same time. In this emerging world, the customer is king and has an array of choice that only the wealthy few could have experienced in preindustrial times."

One lasting result of the new priorities will be to require business of all types to pay more attention to highly selective, individual markets, and this, according to Kelly, "vastly increases the importance of design, inventory control, and communication." He cited advertising as a barometer of change. "Shares of U.S. advertising are already shifting toward forms directly targeted to individuals. Direct mail, for example, is growing, whereas network TV is down."

The reengineering of business

Extending Kelly's belief that information technology represents the leading edge of a business transition toward the customer, Mike Hammer, president of Hammer & Co., stated that three issues will come to dominate virtually every industry in the 1990s—strategic marketing, institutional innovation, and what he terms "the reengineering of business." Said Hammer, "The reasons for the emergence of these three are simple. First, the mass market is dead; second, change has become a constant condition; and third, information technology is opening up radically new ways to redesign your business from the ground up—processes, structures, organizations. And if you don't do it, your competitors will. They will eat your lunch."

As a consultant, Hammer said, he has seen too many firms still fixated on their own needs and their internal problems. "We supply it. They buy it. After that, it's their problem," he said in parody. He doesn't believe such firms can long survive in the new business climate. The basic reason is that they still see every customer as the same. Or, worse, they don't see the customer at all. "There is an important notion buried in the word *customer*," he said, "*custom, customize*—focusing on the specifics. The lingering belief in the mass market has a major drawback today: it is a lie; your customers are not the same. Just ask them."

Knowledge, then, becomes a prerequisite of customer relations because "you can't do anything for your customers if you don't know anything about them," said Hammer. He envisions organizations moving to acquire the tools and the commitment to better understand their customers. The basics as he describes them are market analysis and market segmentation—both drawing on the rapidly expanding capabilities of information technology—and beyond those a strategic market orientation, focused primarily on relationship management. His first imperative for the 1990s, strategic marketing, centers ultimately on service. "Your relationship with a customer is largely a transactional one—you must look at the total relationship and consider that as a basis for services."

Kelly

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As firms reposition themselves toward their customers in an increasingly competitive environment, Hammer and others foresee an evolution toward more resilient organizations. "Change is no longer an episode," said Hammer. "It is a constant condition. And to meet it every business is going to have to cultivate flexibility, responsiveness, opportunism." In Hammer's view, these traits are best developed and carried out in what he calls "the accelerated organization—flat, networked, multidimensional, informed—one that can create ad hoc organizational structures to meet new situations." These are the kinds of structures that best support, and are best supported by, fast-paced information networks.

Hammer emphasized that these new accelerated organizations must embrace innovation in ways not widely practiced today and must be prepared for the greater risks that are inherent in stepping up their innovative activity. "My point," he said, "is that if you want to cultivate innovation, then you have to allow people to fail. The fact is that most innovations are failures; if you expect most of them to be successes, then you are not serious about innovation."

From his own observation, Hammer believes that an orientation toward innovation must become a deeply embedded attribute of corporate style or culture, emanating from the very top. To drive home his point, he told the story of an executive at Citicorp who had been told repeatedly by his management, "Don't ask permission, just get it done." One day, Hammer went on, "this guy had a great idea, he set it in motion, and he executed it well. But it failed. Called into his boss's office the next day, he was handed a promotion. 'But I don't understand,' he said, 'I thought you were going to fire me.' His boss looked up at him and said testily, 'Fire you? I can't afford to fire you! I just spent $20 million educating you!'"

Just as Kelly talked about moving beyond the substitution phase into "deeper adjustments," Hammer talked about "reengineering" to describe the systematic effort to implement radically new ways of working that exploit information technology. "The intent," he underlined, "is not to automate existing ways of working but to find new and better ways." Fond of examples, Hammer used a recent case of innovation at Ford Motor Co. to illustrate how information technology can allow firms to refashion some of their most deeply entrenched patterns of business behavior.

According to Hammer, in the mid-1980s Ford was implementing a major cost-cutting program in which it planned to reduce its accounts payable department from 500 to 400 people by improving and upgrading its information systems. The company was justifiably proud of the prospect of reducing costs by 20%. However, shortly thereafter, Ford representatives went on a tour of Mazda, where the company was a shareholder, and asked to see the accounts payable department. What they found was not 400, not 100, but just 5 people, who were using just one-seventh the computing power of Ford. Analyzing the situation, Ford found that when it had computerized, it had carefully automated the traditional accounts payable process, while Mazda, in contrast, had fundamentally redesigned the process. In short, Mazda got rid of the invoice.

The traditional accounts payable process involves three pieces of paper: a copy of the purchase order sent to the supplier, a receipt from the receiving dock, and an invoice from the supplier. When the three pieces of paper match, a check can be made out to the supplier. A match is processed quickly, but a mismatch, said Hammer, "leaves the accounts payable department in disarray. The problem here is that tracking down mismatches and resolving these problems typically consume 80–90% of the time of the department.

Hammer

"Change is no longer an episode. It is a constant condition. And to meet it every business is going to have to cultivate flexibility, responsiveness, opportunism. These are best carried out in the accelerated organization —flat, networked, multidimensional, informed— one that can create ad hoc organizational structures to meet new situations."

"At Mazda, they eliminated the mismatch problem. They just enter the purchase order into the computer system and put a terminal on the receiving dock. When a part arrives, the guy at the receiving dock simply calls it up, and if he finds it was ordered, he hits a big button that says 'OK,' and in 30 days the computer automatically cuts a check and sends it to the supplier. The innovation here was to eliminate the paper trail by paying on receipt of goods, not on receipt of an invoice. If the order can't be found in the computer, they just send it back."

Ford has since taken up the Mazda approach and has reduced its accounts payable department to 150 people, and to its surprise, financial controls have also improved. "The payoff," said Hammer, "is that for the first time the financial data and physical data match, and the company is set to take the innovation even a step further. It is telling its suppliers that it will pay for parts not on receipt but on use. If suppliers deliver their parts to Ford just in time—that is, on the very day they are needed in Ford's production—they will be paid immediately. Ford is in effect telling suppliers: 'If you match your production to ours, we will reward you.'" Ford's immediate goal in all of this, added Hammer, is to get rid of "the greatest evil in manufacturing today: inventory."

But Ford's simple reengineered system will have still other, deeper impacts. It tends to link the production cycles of two disparate organizations, binding supplier and customer into a new relationship. And internally, it takes disparate departments—purchasing, accounts payable, and receiving—and begins to bind them together into an operational whole. "It's not just the jobs in accounts payable that are impacted by this simple move," said Hammer. "It goes way beyond, from purchasing to receiving to the factory floor to customer relations." In Hammer's view, the reengineering possibilities opened up by information technology will begin to reintegrate the organization, a cohesion that will "turn around the disintegration of the firm into functional pieces that began over 200 years ago with Adam Smith."

Exactly how the industrial organization will evolve in an information-based era was a subject of great interest to the participants, and one to which they were to return.

Voices of concern

Most participants, on the basis of their own businesses and institutions, reinforced Hammer's and Kelly's observations about an evolving customer orientation, and they acknowledged the accelerating dependency of our society on information technology. But at times the room was alive with skepticism and unanswerable questions. Some participants were not comfortable with or convinced of the notion of an information revolution —it seemed overstated, too grand, too sweeping. Others focused on the major hurdles ahead, ranging from software bottlenecks to issues of cultural and institutional inertia. Others clearly foresaw new problems being created with information technology, ranging from issues of privacy to jobs to education to investment policies.

"The hardware is moving very fast," said Walter Baer, director of advanced technology at the Times Mirror Co., "but software shouldn't be glossed over. It remains a major bottleneck, difficult to control and difficult to predict." And Gordon Hurlbert, president of GCH Management Services, added that "the limiting factor in the information business is the high cost of systems development. From my experience in the steel business, we have the conceptual ability to cut costs significantly with information technology, but what delays its implementation is that the systems development cost runs from one to two times the hardware costs. We have got to get the development costs down."

John Armstrong acknowledged the challenge. "We have found exactly the same problem in other industries. And as a result, we now have major R&D investments going into software, application development tools, and connectivity. Roughly 50% of research at IBM is now in software, and the percentage is greater than that on the development side."

Anne Carter, chair of the Economics Department at Brandeis University, pinpointed the nagging question of jobs and job satisfaction that arose repeatedly throughout the two days. "People that participate in our economy want more out of it than just the amenities of consumption. They want good jobs. And our economy is not as proficient at designing good jobs as it is at designing good products. I think this is a central concern for the future. Will information technology help us design better jobs for people?"

Tora Bikson, senior social scientist at the Rand Corp., said she sees evidence of "real potential for job enrichment through information technology." Citing her research on how information technologies mix with and transform the nature of white-collar work, she said that "the adoption of this kind of technology becomes less an event than a process. It takes on a life of its own, with the workstation becoming a real partner in information handling. Given a good tool, people will use it to do the specific task for which it was purchased but will then go on to use it for other applications. It begins to support an expanding array of intellectual and social tasks.

"For example, we took a retirement task force at the Los Angeles Department of Water & Power [LADWP] and randomly split it into two groups and gave one group network-based PCs. We found the level of both task and social interaction to be orders of magnitude higher with the PC group—not only through the network, but they actually met more often, had more telephone contact, and after a year seemed to want to maintain their new contacts. They went on to build a system on their own to interact more broadly with retired LADWP workers by using telephones, computer dialing, and a voice synthesizer. Now they have an on-line retiree directory and skills bank—it will be useful, for instance, if emergency assistance is needed."

Bikson

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Henry Kelly was less certain about the changing nature of work. He acknowledged that "job structure is the most important but also the most ambiguous part of how information technology will be used in the workplace. Two radical poles are still possible: that manual work will be replaced throughout with rewarding, creative jobs, or that we will end up building all creativity into about 10% of the workforce. The jury is still out. There are a lot of policy and economic issues that will help shape this future."

Education will be among the largest of these. It is clear, according to Kelly, that "those without education are going to get clobbered in the emerging work world. The jobs will be less mechanical, less the kind of thing you can learn by watching someone else or by reading a manual. More important in the future will be the ability to work with people, to learn from other people, to create new solutions to unstructured problems, and to work with customers in solving problems."

Interestingly, few of the participants seemed overly concerned about problems of computer literacy in future generations. Rather they seemed far more concerned that the educational process would focus narrowly on technical matters. As Tora Bikson put it, "People are becoming more computer literate, but not broadly educated. The problem is that technical knowledge will continuously obsolesce. In the long run, we need more substantive knowledge, well beyond the computer knowledge."

Benjamin Dysart, professor of environmental systems engineering at Clemson University, added, "I'm concerned with how we bring larger institutional, political, and social problems from the real world into our computing framework. Modeling with supercomputers will certainly help our understanding of some of the higher-order complexities of the environment, say. But as an educator, I'm scared that our students—our next generation of professionals—just might believe that most of the really hard problems in life can be reduced to a form that can be put neatly on a green screen."

Floyd Culler, president emeritus of EPRI, spoke strongly on this point. "Because of pent-up demands for replacing or modernizing the infrastructure of our society, for cleaning up our environment, and for modernizing our manufacturing plants to meet competitive pressures, there will clearly be growing needs for capital goods and skilled services. We will not clean up the environment with information alone—nor will we rebuild our roads, sewers, dumps, airports, and housing stock. To pay for infrastructure improvements will cost a minimum of $10 billion to $30 billion a year, according to a recent National Academy of Engineering study."

Many participants were clearly uncomfortable that an information-driven economy would seem to ignore such fundamentals as the nation's infrastructure. Certainly, telecommuting and teleconferencing would seem to hold out hope for reducing the burden on our transportation system and indirectly our environment. Couldn't they assist in reducing construction costs or streamlining design or improving efficiencies? Such questions were posed time and again.

The potential of these technologies appears strong in concept, but teleconferencing had been an obvious disappointment to most participants. Many had tried it and found the format awkward and the vital social chemistry missing. Someone asked bluntly, "When are we going to have a system that works well enough to begin to reduce our travel budgets?"

Armstrong of IBM said, "In roughly 5 years, we will begin to see the kind of capabilities I think you are looking for—travel budgets should begin to ease. And in 5 to 10 years, we will see entirely new workstations with high-resolution screens with simultaneous voice, visual, and application windows for discussion purposes. Then you will have an interactive system with which you can hold meaningful technical or business discussions."

Robert Johansen, director of new technologies at the Institute for the Future, pointed out that video conferencing is actually growing. "There are now more than 1000 two-way video installations in North America. And there is some real promise that PC technology will drive costs lower and use higher."

Nevertheless, Kelly's data suggest that such systems may be facing an uphill battle in terms of alleviating congestion. "Theoretically, information technology should free you from geographical restrictions. Back offices should be able to go off to the boondocks, people should cease commuting and work at home, business meetings should occur over the airwaves. So far, it hasn't happened. And our population is not spreading out; actually, the concentrations around our major metropolitan areas east and west are increasing. People need access to services to fix things and get things done, and they want direct contact with other people. As a result, the net demand for transportation around cities is getting larger, not smaller. I would describe the transportation area in one word—depressing. There are fewer ideas in this area than almost anywhere else. The key is what will replace the automobile? The automobile is freedom."

With concerns like freedom, mobility, and social contact at issue, the answers to our transportation problems must eventually reach beyond the obvious and pressing—congestion, infrastructure repair, and environmental assault. Certainly one of our limitations is our inability today to envision much beyond the substitution phase—telecommuting for commuting, teleconferencing for conferencing, and so on. The challenge for the next half century will come when we begin to rethink the nature of connectivity and the process of moving about. There is no doubt that information technology will play a central role in this redefinition.

Johansen

"One of the building blocks of the future organization will be the business team—small, cross-organizational, ad hoc, situationally cohesive, task-oriented, and deadline-driven. These teams are where the real work will be done in the future—fueled by the network structure of information technology."

The new teamwork

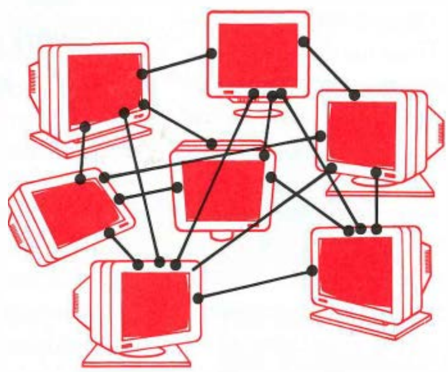
The participants were clearly fascinated by the implications of information technology and by its potential for organizational change. Leading one such discussion, Robert Johansen reminded everyone that "we are a long way from understanding just how the information age will change the organization. Stan Davis, for example, notes in his book *Future Perfect* that we didn't get an industrial organizational model until late in the industrial era—in the late 1920s to the early 1930s—and Davis argues that it will be about 2020 before we have a clear idea of the organizational model for the information-based era."

Nevertheless, Johansen went on to say, it is the emerging conventional wisdom that one of the fundamental building blocks of the future organization will be the business team—"small, cross-organizational, ad hoc, situationally cohesive, task-oriented, and deadline-driven. These teams are where the real work will be done in the future—fueled by the network of information technology."

Part of the larger organizational shift from hierarchical forms toward flatter, faster, more responsive models, the new teamwork concept is cropping up under many different names. Hammer described one variant with the term *accelerated organization*; others use such names as *network-based organization*, *flexible organization*, or *cluster organization*.

"Whatever the name," said Johansen, "there is general agreement that this form of organizational structure is what is needed for the 1990s. This is not just a fad; teams are emerging as a form of bureau-

Connectivity in the Electric Utility Industry



I'm a strong believer that the information age is being driven by connectivity," said James Howard, chairman, president, and CEO of Northern States Power, who led the seminar discussion on the implications of information technology for electric utilities. "When I first arrived at NSP, I looked around at the information side of our business. I found personal computers everywhere, as far out in the boondocks as you can imagine, engaged in every kind of application. And departmental minis were everywhere, but with no design for connectivity. We also had three database management systems and 15 programming languages, and our key systems—power plants and customer service—had become very independent and very isolated."

NSP, like many firms adapting to the strong decentralizing force of computer miniaturization in the last two decades, had computerized department by department, function by function, often with highly incompatible systems. The result, said Howard, was that "vital information became trapped in specific applications, unavailable to most people in the corporation. Overall, I saw lots of innovation, little strategic discipline, and islands of information everywhere."

Linking these islands has become a central strategic issue for NSP, largely because of changes in the industry's business climate. NSP is preparing to operate less as a regulated monopoly and to become more involved in market competition. As a result of the sweeping changes anticipated, Howard is trying to "establish a new strategic outlook on information." Among other things, he sees competition speeding up the decision-making process throughout the industry, requiring faster and better information from all parts of an organization. Managing the information will require a plan to allow the right level and aggregation of information on such matters as operations, costs, markets, prices, and competitive situations to flow into the corporate decision-making framework at just the right time. "Our challenge now," said Howard, "is to unlock that information and make it widely available—to create a new architecture that allows corporate access to key information while still serving critical loc needs."

NSP is now building a "data warehouse" as a pivotal first step in establishing connectivity—and as a mean cratic bypass, driven by things like deregulation, merger and acquisition, and external competition. Virtually all business schools are in strong agreement. It is a conclusion from MIT's Management in the 1990s Program and the thesis of Peter Drucker's new book, *The New Reality*. It worries me a bit because there is now such complete consensus. Team-based organizations are very innovative, but we are now in danger of believing that teams can do everything. We shouldn't idolize them. They are an important new element but not a substitute for bureaucracy.

"Although teams are often very critical of bureaucracies, it is essential that the bureaucracy survive," said Johansen. He and others view the traditional hierarchical organization as a kind of substrate through which the faster, more mobile teams can operate and draw strength. In this construct, the two elements become a mutually supportive and mutually dependent system, with the hierarchy acting as the glue that keeps the renewing but firebrand teams from flying apart.

As Johansen pointed out, such systems of organization have already been extremely successful in a number of industries: "Teams have always operated in aerospace, construction, R&D, and consumer electronics. Teams are not new. What is new is the scale and range of their use." But he foresees some real downside risks in the new teamwork environment. In particular, he feels that the

to uncover some of the potential opportunities for a new, information-based corporate strategy. Howard expects to have the corporate database built within the year, and then it will begin to be filled from all parts of the organization. In a related project, the company is also narrowing the range of hardware and software it uses, with particular attention to connectivity.

NSP is now well positioned to become a leader in the broad area of connectivity, an area that many regard as the next real frontier in information systems in electric utilities. The immediate benefit, as Howard suggests, will be to coalesce the individual functions within an organization into a more competitively paced business entity. But connectivity as a concept is likely to move beyond this initial role as it becomes a strategic tool for realigning relationships throughout the new business environment. Externally, utilities will become linked in new ways to their customers, to suppliers, and to each other. Internally, power plant components will be connected to their operators more comprehensively and in real time. And operators, in turn, will have better links with the outside world through emerging technical support networks, including computerized expert systems. Connectivity, then, is in many ways becoming a metaphor for utility outreach in the new competitive age.

The customer connection may be the most important for the immediate future. Howard commented that because of the regulatory environment, the utility industry has long been focused internally and not on the customer and the marketplace. "This has got to change," he said. "Competition means we are going to have to get closer to our customers, find out what they want, and provide them greater choice. We must come to recognize information as an asset to be managed and tied directly to the strategy of the business." Just how far that strategy will go is unclear, but the implications are large. Mike Hammer laid out the prospect when he said, "Utilities are sitting on one of the greatest undervalued assets in America today—their customer database."

In terms of utility operations, the future implications of information technology are equally large. Howard and others cited numerous examples of cost control in electric utility operations stemming from today's information technology. Technical troubleshooting will take on a new dimension in the next few decades, when utilities are able to draw upon a network of on-line experts and programmed expertise from around the world. And information databases now under development will open a vast array of knowledge beyond the capabilities of individual utilities to acquire.

But the real payoff is likely to come when we are able to superimpose the equivalent of an electronic "nervous system" onto the power plant. Chauncey Starr, president emeritus of EPRI, addressed this potential when he predicted that "real-time diagnosis as a preventive routine is going to be one of the major developments coming out of information technology for electric utilities. This means we will be able to analyze utility operations on a continuous basis, looking for indications of slightly off-normal performance that can warn operators of trouble ahead. We have done this on individual pieces of equipment, but to do it comprehensively is one of the pending developments that supercomputers and expert systems will provide. This will change the availability percentages of power plants from the 60s to the upper 80s. We should see benefits to our industry and to our national economy on the order of $10 billion a year." □

Howard

"Because of regulation, our industry has long been focused internally and not on the customer and the marketplace. This has got to change. Competition means we are going to have to get closer to our customers, find out what they want, and provide them greater choice. We must come to recognize information as an asset to be managed and tied directly to the strategy of the business."

short-term, fast-track orientation of teams will work against the implicit promise of job security and affirmative action in large organizations and, in some cases, against the quality of product or service, even corporate reputation. Tora Bikson observed that "teams are not easy to manage. We have found that they will soon make an end-run around the hierarchy in an effort to get their task done."

Progressive adjustments for dealing with these potential drawbacks—even basic shifts in corporate thinking—will be required if teams are to become a truly accepted part of doing business in corporate America. Compensation has become a critical hurdle in this respect. "So far," said Johansen, "top management has given verbal support, but they are not giving rewards; nor are they relieving the workload. Eventually, as the value of these teams becomes recognized, we will have to give them some rein and find new ways to combine individual compensation with team rewards. We should probably keep our eyes on the Nordic countries, where some interesting compensation models are being formed. As a general rule, these countries are more collectively oriented than the U.S. and more individualistic than, say, Japan."

Understanding what makes teams successful is also critical. Teams, according to Johansen, have a demonstrable life cycle, which—drawing from the Drexler/Sibbet Team Performance Model™—he characterizes as a seven-stage evolutionary process. In stage one, the orientation stage, the basic question before the team is Why are we here? In stage two, trust, the question becomes Who are you? In stage three, goal clarification, it changes to What are we going to do? And in stage four, commitment, it becomes How are we going to do it? Execution of the plan begins with stage five, the implementation stage, and accelerates in stage six, high performance, when the team is moving in high gear. Finally, in stage seven, renewal, the team efforts shift toward trying to diffuse the changes brought about by the team throughout the organization. Presumably at this point the team is abandoned or, in rare cases, rechartered.

Johansen refers to the middle stage in this model—stage four, commitment—as the corner of the process, around which the team focus and dynamics shift from the various preparation stages to action. "Americans," he pointed out, "drive hard to turn this corner quickly, because they are eager to show results. Japanese teams, in contrast, spend much more time in the first two stages, acquainting themselves with the project and with each other and building interpersonal bonds." Experience has shown that shortcutting the early stages does not always lead to a faster conclusion; misunderstandings up front can lead to inefficiencies down the road.

The Team Performance Model is useful in differentiating the needs and relationships of the team at different points in time. Significantly, the kinds of information technology useful in supporting the team at various stages mirror these relationships. The early stages in a team's evolution usually involve a same-time, same-place format (that is, face-to-face meetings in a conference or work room), whereas in stages three and four, team members may be linked from different locations by conferencing-type networks. And by the time team members move out to accomplish their respective missions—the results stages, numbers five and six—they may simply want to keep each other up to date in a different-time, different-place format by leaving and retrieving messages in what Johansen calls "store and forward modes." Laptop computers are important tools for team members on the run operating in the latter stages of high performance.

Groupware is the generic term Johansen gives to these new supporting technologies, which can "help expedite meetings, give teamwork a real boost, and unify members separated by an entire continent," according to the jacket on his book of the same name. "Groupware," Johansen told the participants, "isn't really a new class of products, but rather a new perspective on telecommunications and computing where the end user is now a collaborative team. Building blocks can include local area networks, private networks, PCs, e-mail, workstation environments, gateways, voicemail, and so on. We are at the very early stages of designing environments and tools with a collaborative team in mind. Just look at U.S. business conference rooms. They don't invite cohesion or decision making, there is little sense of focus, and they don't really promote productivity. There is a great deal of room for innovation here. IBM has taken some steps; it has 16 sites set up to help facilitate mostly adversarial meetings, and it is now offering related software and facilitation services in a commercial market test. I usually

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Tora K. Bikson Senior Social Scientist
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James J. Howard Chairman, President, and CEO
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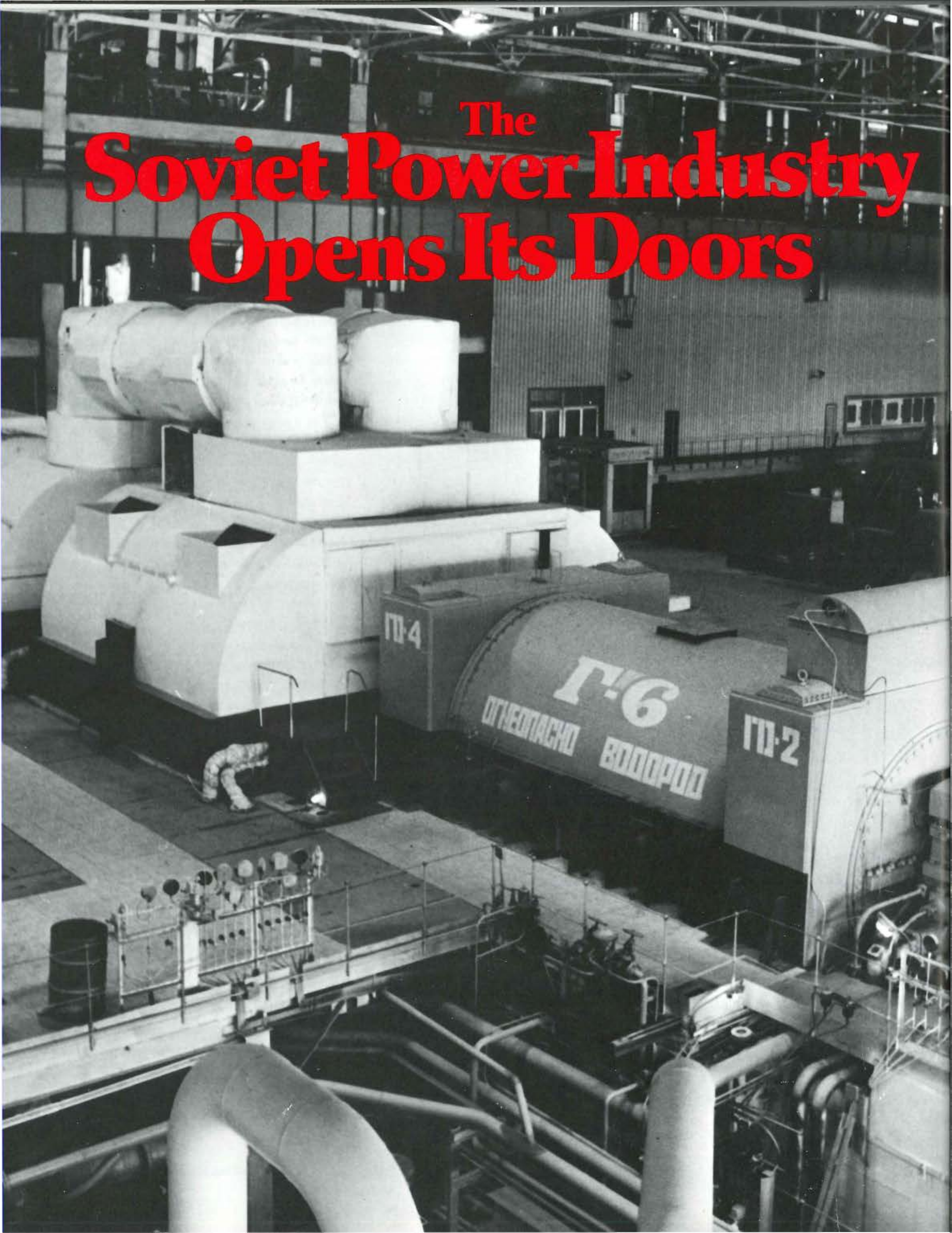
suggest that businesses begin by introducing just a little groupware into their meetings."

Johansen recognizes that the term *groupware* is one of a number of banners for the same type of teamwork support emerging in the computing world. Other terms being used include *group decision support systems, shared systems, data interpretation systems, interpersonal computing,* and *computer-supported coordinated work.* The real point, in Johansen's mind, is not which one will prevail but that "all the labels will probably disappear in 5 to 10 years, because we will take team-oriented information support for granted."

The speed at which information technology can transform business practices—spurring teams, establishing a new reality for the phrase customer-driven, and stepping up the immediacy of ordinary transactions—was an area of clear fascination for the participants. Several marveled at the swiftness with which the fax machine has come to dominate the movement of business information in the last few years.

But more than speed is involved in the way information technology is affecting American business. It is beginning to open new patterns of connectivity, stimulating and supporting the creation of teams drawn from all parts of the organization, forging new bonds with customers and suppliers alike, and giving fresh meaning to the idea of reintegrating the firm—weaving the functional pieces into operational coherence. The challenge for the next decade or two will be to transform this great potential for connectivity into reality. Ironically, the same entrepreneurial spirit driving innovation in connectivity is also the spirit of independence producing a near anarchy of new products and systems. The result is that many firms today are sitting with tens or hundreds of isolated islands of information. Connectivity, then, is both the promise and the challenge of the information era as it opens the twenty-first century. ■

The Soviet Power Industry Opens Its Doors



A tour of the fossil fuel power industry of the Soviet Union reveals a country where the cost of electricity is measured in kopeks per kilowatthour, where huge cogeneration plants pump hot water directly into homes, and where daily plant makeup water peaks at those hours when most people take baths. As if stepping into a different world, the American visitor discovers a land of 16,000-MW power stations, of standardized plant designs, and of centralized authority that can dictate the application of new technologies across the utility grid. Overall, the outsider encounters a variety of sights and practices quite different from anything in the United States—from giant factory test stands for the steam testing of fully assembled turbines to the small, cramped quarters where world-renowned turbine design experts work without benefit of computers.

Yet, as EPRI senior program manager Anthony Armor and Russian-born contractor Ishai Oliker confirmed during their trip to the Soviet Union this past fall, the vast Soviet power industry—with all its apparent strangeness—offers exciting possibilities for information exchange and technical cooperation with utilities in the United States. In this age of *glasnost*, with new doors to the West opening every day, Armor and Oliker became the first representatives of the U.S. electric utility industry to receive an official invitation to see the Soviet fossil fuel power industry firsthand.

As guests of Leningrad's Central Boiler and Turbine Institute (CKTI), the two Americans visited some of the Soviet power industry's major fossil fuel power stations, manufacturing sites, research and development labs, and universities. More than a walking tour, the trip gave Armor and Oliker the chance to meet Soviet utility managers and technical specialists and to discuss operating practices, technology developments, and future possibilities for technical cooperation. The Americans returned with a wealth of

THE STORY IN BRIEF

Two American experts took a fact-finding tour of the Soviet Union's fossil fuel power industry this past fall, visiting some of the USSR's major power plants, manufacturing facilities, research institutes, and universities. The visitors found a number of the Soviets' concerns to be similar to those in the United States—a sharp focus on efficiency and a growing commitment to environmental protection, for example. But the pursuit of these areas has resulted in some intriguing approaches that differ conceptually and technically from present U.S. practice. Computer modeling of new technology has been eschewed in favor of extensive, full-scale in-plant testing. Very large, highly standardized plants are the norm, with wide use of supercritical units. And power plants are often situated near urban population centers to provide centralized district heating to housing complexes.

technical information, some available in an EPRI report, which describes such intriguing aspects of the Soviet power industry as the wide use of supercritical boilers, the use of water chemistry methods exotic to Western engineers, and the use of central cogeneration plants to provide district heating to entire cities. More important, the two utility ambassadors established a bridge for further communication and cooperation between the world's second largest producer of electricity, the Soviet Union, and its largest producer, the United States.

Open discussions

The two-week journey in October 1989 spanned thousands of miles: from Leningrad, near the Baltic, and then inland to Moscow and the Siberian city of Barnaul, formerly closed to Westerners on account of its concentration of power facilities and defense-related industry. "We were warmly welcomed everywhere," says Armor, "with no restrictions on cameras or on access to any part of the power plants or factories. From the moment we arrived in the Soviet Union, we were greeted with openness, enthusiasm, and hospitality."

Throughout the trip, the Soviet hosts freely exchanged information with their American guests. Oliker, a scientist and businessman who worked in the Soviet power industry for nearly 20 years before emigrating to the United States in 1974, served as an interpreter and helped Armor respond to the numerous questions posed by the Soviets at every stop on the tour: What strategies are Americans using for NO_x control? How is profit determined in power transfers between utilities? What progress is being made in the application of superconductors? "In the course of the trip, we and the Soviets

Across the Northern Hemisphere

Their two-week trip last October took EPRI's Tony Armor and Russian-born contractor Ishai Oliker more than halfway around the globe. Traveling by air from San Francisco, the Americans touched down in New York and Helsinki before arriving in Leningrad for their first power plant tour. They later took a night sleeper train to Moscow and then an Aeroflot flight to Barnaul, Siberia.

discovered that we shared a great deal of curiosity about power generation in each other's country, as well as many goals and technical concerns," says Armor.

Discussions reflected a heavy reliance on fossil fuels in both countries. The Soviets have an installed fossil fuel power base of about 249 GW, representing about 75% of their total electric generating capacity, compared with about 500 GW in the United States, accounting for about 70% of the total. The Soviets rely heavily on oil and natural gas, which account for half of their total installed capacity. The export value of these fuels, however, is moving the Soviets toward greater use of coal, a change that can be seen in stepped-up research on pulverized coal and fluidized-bed boilers.

In keeping with their commitment to fossil fuels, both countries make improved fossil fuel plant performance a major thrust of R&D. A need to conserve fuels in the Soviet Union, along with growing concerns about the productivity of heavy industry, is driving the national effort to improve fossil fuel plant availability, heat rate, and service life. Many of these efforts, including the development of new operating practices (such as sliding pressure in supercritical boilers) and equipment designs (for example, titanium turbine blading), parallel utility programs in the United States. In spite of fundamental differences in their supporting economic systems, the Soviet and American power industries face similar economic pressures to conserve fuels, optimize the use of their existing capacity, and develop designs for more-efficient future power plants.

In addition, both Soviet and American power producers are balancing their technology decisions against environmental concerns. A new environmental awareness has surfaced in the Soviet Union in just the past few years, including a stated intention to reduce emissions from fossil fuel power plants to levels now accepted in Western Europe and the United States. In the course of the trip, Soviet utility personnel constantly raised environmental issues in their discussions with the Americans, emphasizing their increased use of environmental control technology and interest in Western equipment and approaches. In a joint venture that typifies the entrepreneurial "cooperatives" now permitted under Gorbachev's *perestroika,* the Soviets have recently teamed up with Finnish and West German manufacturers to form Energy-Ecology-Engineering (EEE), an organization that will develop new emissions control technology and—if all goes as planned—market it to the world.

As reported to Armor and Oliker, the Soviets have now started to explore environmental controls such as flue gas SO_2 scrubbers, which have not yet been fitted to the great majority of their fossil fuel plants. The Scandinavian Flakt group, however, is already supplying advanced electrostatic precipitators for old coal-fired plants, while the West German firm Steinmuller is designing a catalytic NO_x reduction system for a modern cogeneration facility in Leningrad. In Barnaul, Siberia, an ambitious program in fluidized-bed combustion design is under way. In addition, the Soviets are seeking to reduce emissions through improvements in the efficiency of existing capacity, including the retrofit of cogeneration equipment for district heating to older electric generating stations.

Going supercritical

An important factor in Soviet efforts to improve the thermal efficiency of their power plants is their use of supercritical boilers for more than 35% of their fossil fuel plant capacity. The Soviets installed their first 100-MW supercritical unit in 1966 and have since emerged as the world's largest supercritical power producer. Today, they have almost 220 supercritical units in operation at both cogeneration and electric-only plants, with standardized ratings of 300, 500, 800, and 1200 MW. The United States has about 170 units, and Japan, approximately 60. The Soviet Union and its trade partners in Eastern Europe, Cuba, and mainland China have now installed more supercritical boilers for electric power production than the rest of the world combined.

For Armor and Oliker, the tour offered a chance to study the Soviet response to some of the operational and maintenance problems that have beset supercritical units in the United States, Western Europe, and Japan. An EPRI report recently documented the excellent availability record of later-generation supercritical units in the United States—as good now as subcritical units. Operating problems with the first wave of units (ordered in the 1960s and 1970s), however, caused supercritical units—in spite of their performance advantages—to fall out of favor with most U.S. utilities ordering new plants.

As many U.S. utilities know from experience, the increased steam pressures and temperatures in supercritical units can improve the thermal efficiency of fossil plants by up to 5% over a good subcritical unit; yet operation with supercritical steam conditions requires careful startup and control practices to avoid severe stresses on boiler and turbine components. In addition, supercritical units demand exacting attention to water chemistry if the supercritical fluid is to be kept from carrying corrosive impurities to the boiler and turbine.

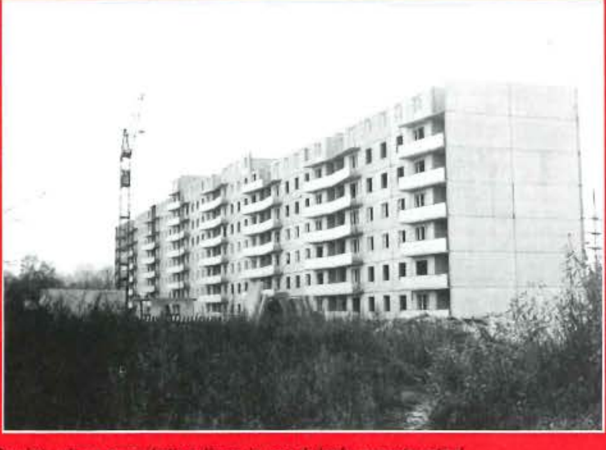
Armor and Oliker were particularly interested in the Soviet practice of injecting oxygen into the feedwater of supercritical units to control corrosion. This neutral-oxygen water chemistry treatment, so called because of its high concentrations of oxygen and maintenance of a pH between 7 and 8, represents an approach nearly opposite to the all-volatile treatment (AVT) used in most American supercritical units, where hydrazine and ammonia are injected into the feedwater to reduce oxygen concentrations.

Rather than fighting oxidation with AVT, the neutral treatment encourages it.

IMAGES OF A CHANGING SOCIETY

Red Army soldiers were happy to pose with Armor at the Kremlin.

A Finnish-operated restaurant in Leningrad reflects the Soviet trend toward joint ventures with foreign business interests.



Most of the Soviet urban population lives in modularly constructed housing units like this one going up near Moscow.

Oliker with Soviet schoolchildren in Leningrad; another group of children, from Moscow, are now pen pals with California grade-schoolers taught by Armor's wife.

Moscow's district heating system supplies hot water year-round to an 8-acre outdoor public swimming pool.

A streetside exhibit in Moscow's Arbat district displays the latest in Soviet popular art.

The oxygen added to the feedwater reacts with iron impurities to form a protective black magnetite oxide film on the inner walls of steel tubes and other components. According to the Soviet specialists, injection of hydrogen peroxide into the feedwater, which quickly decomposes into oxygen and an OH radical, is the most effective variation of the neutral treatment. At some stations, however, the Soviets treat feedwater with gaseous oxygen. At one Moscow power plant, Armor and Oliker watched as engineers injected air directly into the condensate to achieve oxygenation.

Soviet field tests show that the neutral-oxygen method produces only half the iron concentrations in boiler feedwater and steam that AVT does, while reducing the need for chemical cleaning and improving the operating flexibility of the boiler. One drawback of the method is that it cannot be used with copper-alloy components, which may corrode faster under neutral conditions than with AVT. To overcome this problem, the Soviets have developed a modified, combined treatment that uses small concentrations of ammonia and a slightly higher pH and that is said to work better than AVT on copper-alloy tubing. In general, Armor and Oliker were sufficiently impressed with the Soviet use of neutral treatment to pinpoint it as a high-priority topic for further investigation in the United States. In work that will draw directly on improved communication with the Soviets, EPRI plans to initiate research later in 1990 to explore the possible usefulness of the neutral and combined treatments in U.S. supercritical units.

A related Soviet operating practice that caught the attention of Armor and Oliker is a unique approach to variable-pressure operation, a strategy in which steam pressure in the boiler is varied to match load shifts, improve heat rate, and avoid stresses in the turbine and valving. The Soviets slide the pressure in their furnace walls down through the critical point as loads are reduced, reaching subcritical conditions, and then go supercritical again when demand for power increases. The Japanese also slide the pressure in their supercritical units this way; however, they use a complex, spiral tubing in their furnace walls (also now used in two U.S. subcritical units) that is designed to prevent temperatures from getting too high as flow conditions change within the tubes. The Soviets, by contrast, use the more conventional, vertical tubing in their boiler walls; yet they appear to be enjoying the heat rate and operational benefits of the sliding pressure mode without significant tube failure or availability problems. A closer look at their boiler designs, operating practices, and availability data might yield information valuable to U.S. utilities, many of which are considering modifying older units for variable-pressure operation and would like to do so without making major changes in boiler design.

The promise of district heating

The wide use of cogeneration plants for district heating is another remarkable feature of the Soviet utility landscape that received special attention from Armor and Oliker. In contrast with the United States, where cogeneration is mainly the province of independent power producers and where only a few utilities operate district heating plants, cogeneration in the Soviet Union is a large-scale, centralized activity that encompasses more than one-third of all steam-electric power plants. First established in the 1920s, Soviet district heating has always been at the center of efforts to conserve fuels; and now, as environmental awareness grows, it is increasingly viewed as a key to minimizing emissions.

As guests at the Southern heat and power station of Lenenergo, the utility of Leningrad, and at power station 26 of Mosenergo, Moscow's utility, Armor and Oliker viewed two different approaches to district heating. The 500-MWe, 1100-MWth Southern station, one of several plants in Leningrad's open district heating system, delivers hot water directly to the residences of more than 150,000 people for everyday uses, such as bathing, and for space heat. Morning and evening bath times are indeed the peak hours in such a system, which must constantly draw on a flow of makeup water from the city's main supply. Lenenergo, the first Soviet utility to use district heating, now supplies 35 billion thermal kWh of heat per year to 13,000 buildings, 45% of Leningrad's heat load. A utility comparable in capacity to the largest in the United States, Lenenergo maintains 10,000 MW of installed power, including 12 cogeneration plants, 6 hydro facilities, and a 4000-MW nuclear station.

In contrast to Lenenergo, Mosenergo operates a closed system that pipes hot water through heat exchangers at residential and industrial sites, supplying both heat and electricity to more than 85% of the national capital's 9 million people. The Moscow network even supplies heat to a huge outdoor bathing pool that covers more than 8 acres, where the city's inhabitants find steamy relaxation in spite of surrounding winter temperatures of –30°C and below. Another impressive landmark in the Mosenergo system is station 26, the world's largest district heating plant, which occupies 90 acres and is typical of a Soviet trend toward large, modularly constructed, multiunit power stations. It contains two 80-MW subcritical and seven 250-MW supercritical units with peak capacities of 1410 MWe and 4000 MWth. Five pipes, each 5 feet in diameter, deliver hot water at 135°C from the station and wind through Moscow for more than 25 kilometers. Makeup water flows from the Moscow River, 13 kilometers away.

Apart from impressing the Westerner with their size, these district heating systems make striking examples of total plant utilization. The Southern station operates as a baseload plant through the depth of the Leningrad winter, using virtually all its condensed water for heating. The resulting midwinter heat rate of approximately 6000 Btu/kWh is close to the maximum efficiency a power plant can achieve, contributing to the published year-round average of 7680 Btu/kWh for all Soviet district heating plants—about 15% better than the best U.S. fossil fuel electric plant and 23% better than the U.S. average.

The economic advantages of such highly efficient plants, combined with the opportunity to limit emissions in urban areas, could encourage the development of new district heating schemes in the United States, where only a few, smaller plants are in operation today. Another alternative under study for EPRI is the use of district heating plants to provide chilled water for cool storage and air conditioning to customers at warmer times of the year, a strategy that could help utilities manage loads and improve year-round efficiency.

"There is a potential opportunity, through technical cooperation with the Soviets, to develop and expand the use of district heating and cooling in both parts of the world," says Oliker. "The trend toward international cooperation on environmental issues such as acid rain, global warming, and reductions in greenhouse gases could further motivate the two countries to work together in this area."

New designs

As they moved between power plants and major Soviet R&D institutions and manufacturing facilities, Armor and Oliker noted work in progress on a number of innovative designs for boilers, turbines, heat exchangers, and other kinds of generation equipment. The design of last-stage turbine blading—built of titanium—for a 1200-MW tandem compound supercritical unit was the subject of a brief meeting at CKTI in Leningrad with Professor L. M. Zesina, a world authority on turbine hydrodynamics. The American visitors noted a striking contrast between the high quality of work at that institute and the small cubicles and gloomy surroundings in which Professor Zesina and the other scientists conducted their research. Both at CKTI and later at Moscow's All-Union Heat Exchange Institute (VTI), personal computers, individual telephones, facsimile machines, and copiers were nowhere in sight. Yet, as Armor reports, "the hand-drawn turbine blade designs and detailed calculations that Professor Zesina carried in a portfolio under her arm, representing a lifetime's work, would probably measure up to any in the world."

For Oliker, formerly a senior scientist at CKTI, the visit was something of a professional reunion, and included surprising news from former colleagues that a recirculation water deaeration system that he had designed in the early 1970s has now become standard equipment at Lenenergo district heating plants. "Almost nothing had changed in the equipment or physical layout of the institute since my leaving in 1974," he says. "My old work area, the people working nearby, the arrangement of furniture were all almost exactly the way I had left them."

Against this background, which appeared to be frozen in time, the Americans found the Soviets designing for the future. At both the LMZ turbine factory in Leningrad and the Sibenergomash boiler factory in Barnaul, Armor and Oliker were impressed by advanced technology designs, including many features unique to the Soviet Union.

The LMZ factory, which has been producing heavy machinery since 1857, constructs turbines for nuclear, fossil fuel, and district heating plants. Of the 15,000 employees, there are 7500 qualified engineers, 500 in the turbine design group alone. During the factory tour, the Americans saw shrouded titanium blading being assembled for the last-stage blading of eight 1000-MW nuclear units, control stages that alternate ferritic and austenitic blading for lock-tight operation under temperature, and designs to eliminate keyways in turbine disks—frequently the cause of maintenance problems in Western turbines.

The huge Barnaul boiler factory includes buildings from a German Messerschmitt plant captured by the Soviet Army at the end of World War II; they were disassembled and hauled in pieces to the Soviet Union. The factory now produces hundreds of boilers each year for the cement, fertilizer, metals, and power industries. Talking shop with the resident boiler experts, Armor and Oliker learned of innovative designs already in service: a compact, 215-MW tangential-fired annular boiler at Novo-Irkutz and a 150-MW low-NO_x unit at Ustilinskaya that uses a spiraling fireball to burn poor-quality coal in 1-inch pieces. They also saw designs for boilers that burn coals with high ash content, including an open-cast lignite coal that is 40% ash, 40% water, 10% oxygen, and only 10% fuel.

Also in Barnaul, at power plant 3, Armor and Oliker watched CKTI field-testing of a new generation of fluidized-bed combustion (FBC) boilers that the Soviets plan to implement on a wide scale in the 1990s and into the next century. The Soviets have already installed many industrial FBC boilers and are completing a much larger, 135-MW bubbling-bed utility version that is now being installed at power plant 3, a large cogeneration facility serving more than 300,000 people. This unit will undergo a two-year test program to burn coal from the Kansch-Achinsk region of Siberia. The hope is that the abundant calcium in this coal will absorb pollutants from the combustion gases and thus make it possible to operate the boiler without the addition of the limestone used in most FBC designs. A separate project to design 500-ton/hour circulating-fluid-bed boilers for utility use is also under way at the Sibenergomash factory in Barnaul.

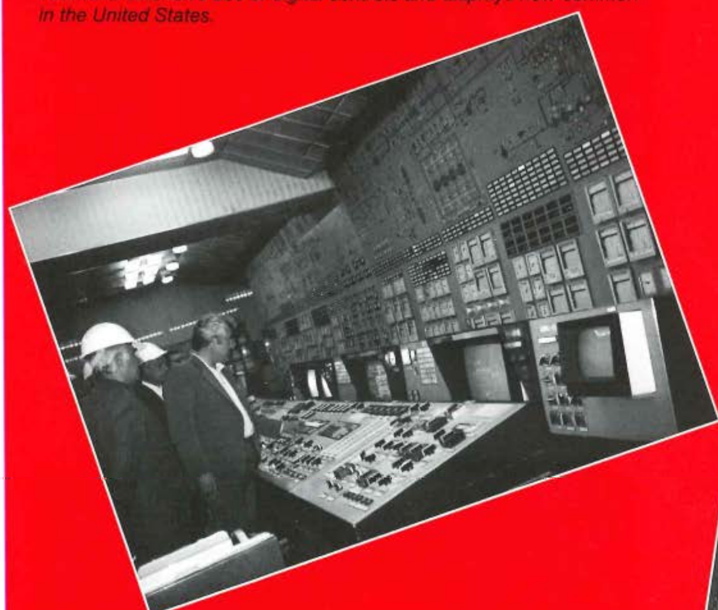
The FBC site at Barnaul was just one of the outstanding Soviet test facilities noted on the trip. At CKTI in Leningrad, Armor

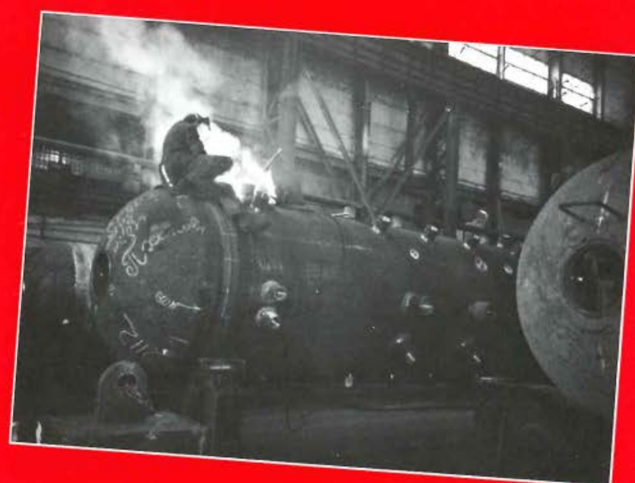
INSIDE THE POWER INDUSTRY

Professor L. M. Zesina, a world-renowned authority on turbine hydrodynamics, displays the turbine designs she keeps in a hand-bound volume.

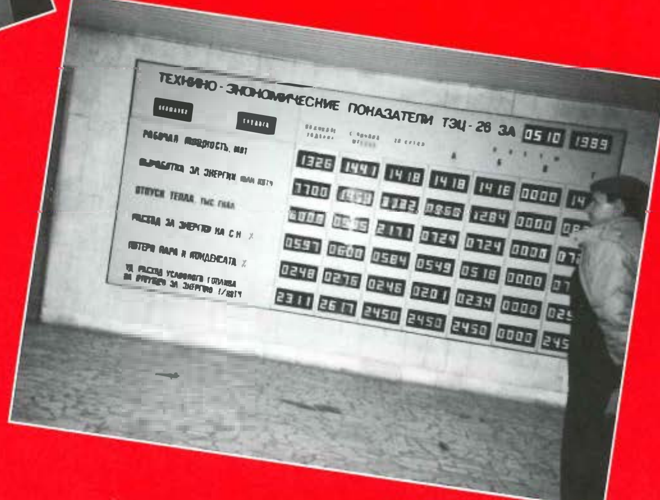
The top management of Mosenergo, Moscow's utility, met with Armor and Oliker to discuss electricity generation in both countries; the utility's director general, N. I. Serebryanikov, is third from the left.

The control room of a modern district heating plant in Moscow does not make extensive use of digital controls and displays now common in the United States.



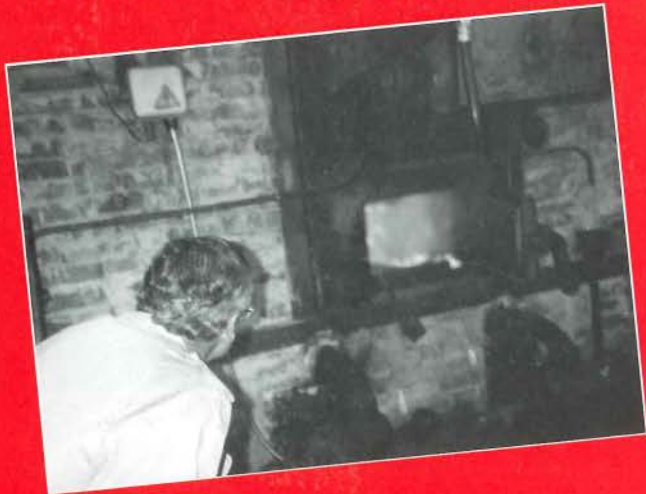


Workers in some physically demanding trades, including welders at the Sibenergomash boiler plant in Barnaul, can retire as early as age 50.



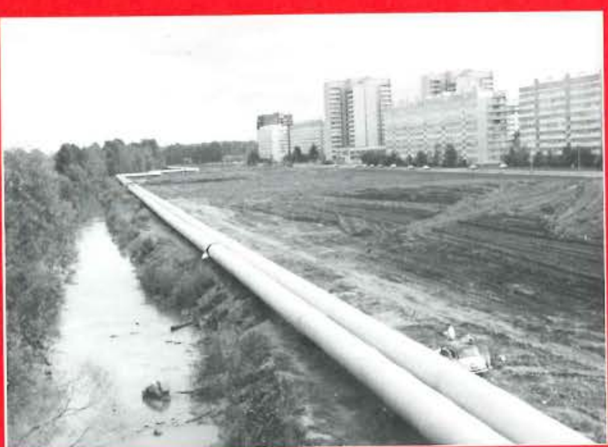
An on-line performance tally at the main entrance of Moscow's station 26 keeps employees posted on the plant's key operations figures.

DIRECTIONS IN SOVIET TECHNOLOGY



This 6-ton/hour bubbling-fluidized-bed test boiler at the Central Boiler and Turbine Institute's Barnaul facility is representative of new Soviet initiatives in emissions control.

A supercritical district heating turbine at Moscow's station 26 reflects the Soviet commitment to the efficiencies of supercritical operation.

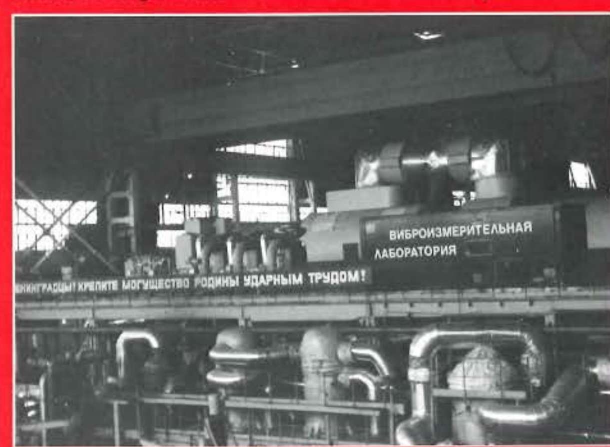


Five-foot-diameter pipes in Leningrad's district heating system deliver hot water directly to users in thousands of apartments; for scale, note the car parked next to the piping.

The Sibenergomash factory in Barnaul is pursuing innovative boiler designs for improved burning of high-ash Siberian coals.

This condenser at station 26 is one of many specialized components developed by the Soviets for district heating.

In-plant testing of new technology, a common Soviet practice, is seen in this turbine-vibration-monitoring trailer at Leningrad's Southern station; the slogan reads "Work hard for the common good."



and Oliker saw a 30-ton boiler capable of supercritical conditions that is used exclusively for testing. Even more impressive by virtue of sheer size were the six turbine test stands in the cavernous reaches of the LMZ turbine manufacturing plant. Linked to an on-site 300-MW power plant, these huge fixtures allow factory steam testing of fully assembled turbines as large as 1200 MW—a capability not available in the United States.

For Armor, whose work in fossil fuel plant performance has taken him through manufacturing plants in North America, Europe, and Asia, the unique Soviet test facilities in both factories and power plants suggested a possible new field of opportunity for large-scale testing of technologies developed in the United States. He also noted that the Soviets had little reluctance to test new technologies in the power plant, a practice that might provide U.S. utilities with opportunities for quick field tests. Through such arrangements, the Soviets might gain access to technologies such as digital diagnostics and environmental controls, in which they lag behind the United States.

"There are definite possibilities for cooperative work of benefit to both the United States and the USSR," says Armor. "And the possibility of using test facilities and power plants adapted for the effective use of low-rank coals may be of real interest to our utilities. Although it would have been unthinkable 10 years ago, today it's not hard to imagine working together with world-class institutes like CKTI and VTI—or even with Soviet contractors if the payoff is there."

Modular plants

Beyond the value of their test facilities, the Soviets might also offer valuable lessons to U.S. utilities in modular plant design. The Soviet use of large, centralized power stations, represented by the gargantuan, 16,000-MW development at Ekibastus, Siberia, is part of a commitment to multiunit installations that are built over time in standardized increments—from gas turbines of a few megawatts to 1200-MW supercritical units. While reducing the range of design options, centralized authority speeds the construction process by establishing standardized ratings and designs that can be replicated by different manufacturers. In most Soviet plants, the dimensions of turbine halls and their wall panels, beams, roofing, and cement foundation blocks have been standardized. The use of these prefabricated components leads to quite spacious plants; however, the Soviets claim that the standardized approach more than pays back the civil engineering costs of extra size. U.S. utilities now exploring ways to quickly but gradually add capacity at existing power stations may want to assess this Soviet experience, particularly with regard to the economics of trading away design options for a faster construction path and reduced capital outlays.

The integration of the Soviet power industry with the educational system is another case where centralized authority seeks to achieve an efficient result, albeit while limiting individual choice. Armor and Oliker took time on their trip to visit the prestigious Moscow Power Institute (MPI), where the more than 2000 engineers and technicians who graduate each year are educated specifically for careers in the power industry. The students actually become part of the industry when they enter school, training for specialties —such as water chemistry engineer or controls specialist—that will be their careers, often for life, upon graduation. Or, they may go on to become part of the research staff at their institute, which is involved in everyday industry operations and field testing. MPI and other Soviet academies provide the Soviet power industry with a steady flow of talented, technically trained young people, an achievement that could stir envy among U.S. utilities recruiting from a dwindling pool of graduates. The well-developed programs at these Soviet centers of learning and research would appear to make them ideal candidates for student and faculty exchange, information give-and-take, and a general opening of communication with educational institutions in the United States.

From the campus to the power plant, the Soviets are opening a world of opportunity for cooperation between the planet's two largest power industries. The awakening of a new, enterprising spirit in the Soviet Union was evident to Armor and Oliker at every stop on their trip—from the privately owned fast-food stands and barbecue grills now springing up along highways to major, international joint ventures such as the Energy-Ecology-Engineering group. Everywhere they traveled in the Soviet Union, Armor and Oliker found their hosts eager to initiate cooperative ventures with utilities and other organizations in the United States.

As doors open and barriers come down, U.S. utilities may choose to explore the opportunities that wait along the path cleared by Armor and Oliker. A next step might be an official visit to the Soviet Union by a committee of utility executives, who could assess for themselves some of the opportunities for cooperative work. This committee might then report back to EPRI with recommendations about the future of the U.S.-Soviet utility relationship.

As Armor sees it, speaking from more than 20 years of experience in the power industry of the United States, "We and the Soviets share the same needs to make efficient use of our fuel resources, to protect the environment, and to provide our homes and industries with electric power. Our power industries appear to be one area of life where we can focus on our similarities instead of our differences." Oliker, invited back to his native land after 15 years away, underscores the same thought when he says, "I never thought this day, and this opportunity, would arrive in my lifetime." ■

This article was written by Jon Cohen, science writer, from interviews with Tony Armor, Generation and Storage Division.

TECH TRANSFER NEWS

PG&E Research Serves Up Better Burgers

What's it take to cook a stack of hotcakes, a hamburger, or some hash browns exactly right? The fry cook goes by a practiced eye and nose, but whoever runs the business has to go by the books. Even the griddle behind a fast-food counter is subject to audit for its energy efficiency and cost.

But how to measure and compare performance? Thanks largely to Pacific Gas and Electric, there's now a uniform test method that is impartial as to energy source and can be used across the foodservice industry. It has been approved by the American Society for Testing and Materials as ASTM F-1275, "Standard Test Method for the Performance of Griddles," and is effective this month, March 1990.

Until now, griddle manufacturers offered a variety of tests for gas and electric models, making it difficult for commercial users to compare alternatives. As an official of the National Restaurant Association put it, "We've had UL and AGA certifications to tell us a griddle is safe, but we've never known if it will cook a hamburger." One procedure, for example, measured the full-load energy required to boil water. But this didn't account for the range of energy expended in typical use, from cooking just a few patties to cooking a griddleful. The new method specifies uniform procedures for measuring energy performance at low, medium, and full loads; it also measures idle energy use and griddle surface temperature uniformity.

PG&E's research was nothing if not thorough. The utility enlisted the cosponsorship of EPRI, the Gas Research Institute (GRI), and the National Restaurant Association and then conducted more than a year of work in its test kitchen. Thousands of rigorously uniform hamburger patties were used.

EPRI project manager Karl Johnson, chairman of the ASTM subcommittee sponsoring the test method, is enthusiastic about the results. "The data and documentation ASTM got from PG&E really speeded the committee's consensus," he says, "and the ASTM test method is an authoritative way to transfer such research results to the foodservice industry."

Johnson says that PG&E—still with EPRI and GRI sponsorship—now has work under way toward a uniform test procedure for deep-fat fryers. And plans are afoot to develop test methods for ovens, steamers, combination ovens, ranges,

and broilers during the next several years. "Nationwide, utilities serve more than 730,000 foodservice organizations, which buy about $800 million of cooking equipment every year," says Johnson. "Utilities have an important stake in promoting efficient energy use." ■ *EPRI Contact: Karl Johnson, (415) 855-2183*

Hands-On Classes in EMF Measurement

The facilities of EPRI's High-Voltage Transmission Research Center at Lenox, Massachusetts, are proving to be almost made to order for a new research and educational effort focused on the measurement, analysis, and prediction of magnetic fields created by various sources in ordinary household settings.

General Electric, which operates the center, has built a 1200-foot length of 23-kV, three-phase distribution line and is now completing a test house to simulate various combinations of grounding systems and appliance loads. One workshop on electromagnetic field (EMF) measurement was held in each of the past two years, and two more are now scheduled for 1990, reflecting the growing utility interest in EMF.

Greg Rauch, the project manager for EMF measurement technology, emphasizes the practical nature of the effort—hands-on experience with various instruments on the market for magnetic field measurement, and special attention to the problem of distinguishing among the many EMF sources that may be present.

Workshops are limited to 35 participants. Each workshop is 1½ days long, and the $1600 cost for each utility includes an EPRI-developed stand-alone recorder (STAR) and accessories. STAR measures 60-Hz magnetic fields and logs them on three orthogonal axes, together with records of time and distance.

The new test house is actually a shell, with just one finished bathroom; other interior walls have been left unsheathed so that wiring and appliance configurations can easily be altered. The house is "surrounded" by a simulated subdivision of 17 other homes—service drops and variable-load boxes that create authentic conditions on the distribution line.

Most residential magnetic field sources are obvious, Rauch admits—primary (4-kV and up) and secondary (120–240-V) distribution lines and cables, and conventional appliances. But he also cites noncode or unusual field sources, such as multiple electrical grounds in a house or the third wire added to establish two-point control of a hallway light. Also, ground return currents cause magnetic fields around the metal water piping often used for grounding household electrical, phone, and cable TV services.

EMF measurement instruments are not new for the most part, according to Rauch, but standard protocol for their use is only now evolving through EPRI-sponsored research. "That work is about 98% complete," Rauch says, "and the next step will be to develop a model—a computer program—to predict fields.

"The test house gives us the opportunity to manipulate conditions, too—to change grounding, for instance. That will add tremendously to the value of the workshops, over and above the training in EMF measurement." ■ *EPRI Contact: Greg Rauch, (415) 855-2298*

Nuclear Plant Software Goes to Detroit

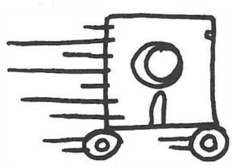
Heating, ventilating, and air conditioning (HVAC) systems for General Motors cars will be the unexpected beneficiaries of an artificial intelligence (AI) tool first developed for EPRI members to use in nuclear power plant applications. PLEXSYS (plant expert system) is a programming tool for developing software to be used in expert systems. Its claim to fame is its convenience for users who know power plants but not computer programming.

Introduced two years ago, PLEXSYS can represent plant components, subsystems, and systems and their functional interdependencies, and it can manipulate their behaviors to simulate various circumstances. The package is a specialized extension of an expert-system development tool called KEE (Knowledge Engineering Environment), which is based on a sophisticated AI language called LISP. PLEXSYS combines and integrates those languages, transliterating them to simpler form for applying artificial intelligence.

When PLEXSYS was demonstrated at the GM Technology Center, its potential was so clear that CEO Roger Smith authorized corporation-wide licensing for unlimited use. For the first application, GM expects to model HVAC components (shapes, sizes, material specifications) and behaviors (power requirements, working fluid flow rates, performance coefficients, and so on) and their all-important interdependencies. Any number of "if . . . then" system design alternatives can thereafter be tested against such variables as power and space in the conceptual envelope of a new car.

An analogous power plant application is the piping and instrumentation of an emergency feedwater system, replete with valves, pumps, controls, and interconnections for a seemingly endless list of functional arrangements. PLEXSYS can model that system and separately model various problems and their solutions.

PLEXSYS can do more than aid the designers of power plant systems. It also can help plant operators by automatically determining the operability of a system or subsystem on the basis of the status of its components. Shift crews can use PLEXSYS in training for emergencies—trying different approaches and immediately learning the consequences. Similarly, it's a means of reliability analysis, a way to extrapolate fault trees from low-level failures up to serious events.



PLEXSYS was developed for EPRI by Intellicorp, which is helping to commercialize the package among utilities and elsewhere. General Motors is one of several prospective users outside the electric utility industry. UK-Shell, another licensee, is expected to use PLEXSYS in planning its North Sea oil distribution network of ships, pipelines, and storage facilities and in making output forecasts for up to 30 years. And Toshiba has licensed PLEXSYS in Japan, both for its own use and for marketing in that country. ■ *EPRI Contact: Siddharth Bhatt, (415) 855-8751*

Top-Loading Fuel Cask Costs Less to Handle

A new kind of concrete storage system for spent nuclear fuel is expected to prove easier and less costly to handle than previous systems made of either concrete or metal. Demonstration this spring will be jointly funded by EPRI, DOE, Wisconsin Electric Power, and Pacific Sierra Nuclear (PSN). PSN is furnishing the prototype cask, and researchers at DOE's Idaho National Engineering Laboratory (INEL) will conduct the tests.

The demonstration unit will hold 17 PWR spent-fuel elements (a standard cask of the same design would hold 24). The test regimen will measure both thermal and radiation performance—the ability to dissipate heat and provide adequate gamma and neutron shielding.

The new system includes a ventilated concrete cask and a sealed inner container for the fuel. Annular airflow paths between cask and container walls are designed to dissipate decay heat by natural circulation. But the novel feature is top loading, which should make for faster handling as well as simpler machinery. The whole system is expected to cost less than today's systems because the free-standing cask can be built in a supplier's shop and delivered where needed.

A topical report on the standard, 24-element cask design has been submitted to the NRC; it has elicited a list of questions, some of which are expected to be answered by data from the demonstration at INEL. When the topical report is eventually approved by the NRC, utilities using the PSN cask technology can cite the report in support of their site-specific license applications. ■ *EPRI Contact: Ray Lambert, (415) 855-2788*

Residential Program

Integrated Heat Pump System

by Arvo Lannus and John Kesselring, Customer Systems Division

ABSTRACT *A new air-source heat pump has been developed that integrates efficient space conditioning and domestic water heating into one system. The heat pump incorporates electronically commutated, brushless dc motors in the compressor and the indoor blower drive and has a tube-in-tube refrigerant-to-water heat exchanger that acts as a condenser for heating water and as an evaporator in the defrosting mode. The refrigerant-piping scheme avoids the problem of refrigerant and oil accumulation in the unused heat exchanger and uses only three flow control devices. Production of the unit in 2- and 3-ton capacities has begun.*

Rising energy prices and greater consumer emphasis on comfort and service have created a growing market for high-efficiency space-conditioning equipment in the United States. In late 1982, EPRI joined with Carrier Corp. to develop an advanced air-source heat pump. The goal was to meet the consumer's need for improved efficiency and comfort as well as the electric utility industry's need for end-use equipment that, while conserving energy, does not degrade electrical system load characteristics.

Since this project began, the development of high-efficiency equipment has been given additional impetus by the adoption of federal minimum-efficiency standards, which will become effective for split-system heat pumps and air conditioners in 1992. These standards will render obsolete about 90% of the products manufactured today. Moreover, the growing worldwide concern over global climate change may ultimately require combustion-energy-using equipment (including electrical equipment, since electricity generation in the United States is over 70% fossil fuel based) to be as efficient as technologically feasible.

Objectives and initial studies

EPRI had several technical objectives in launching this project: high heating efficiency; high cooling efficiency; good dehumidification capability; low indoor and outdoor sound level; peak power demand reduction (0.67 kW per nominal ton of capacity) and demand-limiting controls; improved defrosting capability; thermostat setback and setup controls; and water-heating, thermal storage, zoning, and reliability characteristics commensurate with those of existing heat pump products.

These technical objectives were set on the basis of an analysis of air-source heat pump equipment on the market in 1982 and the projection of efficiency trends to 1987, the expected completion of the research project. It was recognized, however, that the targets might have to be tempered by manufacturing and economic considerations, especially if engineering feasibility and market analysis studies, to be conducted during the first phase of the project, revealed the targets to be unrealistic.

The initial project phase involved the technical screening of a wide variety of improved component options (e.g., variable speed, ice storage, hot water storage, use of nonazeotropic fluids) and system configurations (economizer cycle, Granryd cycle, nonreversing refrigerant circuit). Some of the configurations were analyzed in greater detail by computerized engineering-design codes, which were validated by tests on laboratory systems. These studies led to the choice of the final design, which incorporates a variable-speed compressor and fan and uses a novel refrigerant-piping scheme for integration of the water-heating function.

System design

The heat pump system consists of three major components—an outdoor fan/coil unit, an indoor fan/coil unit, and a compressor unit—coupled with a standard electric (or gas) water heater (Figure 1). The outdoor unit employs a multirow, louvered-fin heat exchanger and a single-speed fan and is the only component exposed to weather. The indoor unit is very similar to a standard fan/coil unit, except for the variable-speed fan drive. As in conventional systems, the supplemental heating elements are located in the indoor fan/coil unit. The compressor unit represents a new design: it contains a hermetic, reciprocating compressor driven by a permanent-magnet dc motor; a tube-in-tube heat exchanger with two double-wall, vented refrigerant tubes encased in a water tube; a stainless steel water-circulating pump; system control and electronic drive modules; an accumulator; and flow control valves and other "pumping" components.

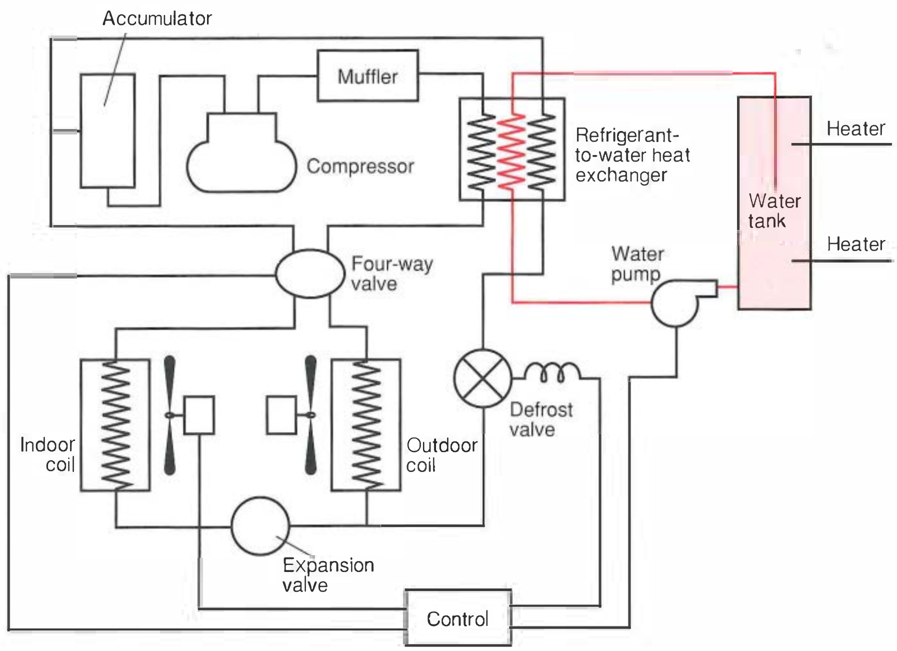
The variable-speed drives for the compressor and the indoor fan are brushless dc motors that have a three-phase stator and a rotor with four-pole ceramic permanent magnets, mounted circumferentially. The motor drive was developed by General Electric Co. in conjunction with this project and is now in limited production. The use of a variable-speed drive with a standard production compressor required some compressor redesign.

Water heating by heat pumps and air conditioning systems is not a new technology. Desuperheater coils were introduced on these systems almost 10 years ago, and heat pump water heaters (dedicated air-to-water heat pumps fitted to hot water tanks) have been marketed with varying success for almost that long. There have also been attempts to combine a water-heating condenser with the heat pump refrigerant cycle. All of these designs have employed rather complex refrigerant circuitry and a multitude of flow control valves, however, and most were never commercially introduced.

The refrigerant circuit of the new integrated heat pump system is covered by two U.S. patents, with foreign patents pending. The concept is simple, involving a tube-in-tube heat exchanger (with two refrigerant circuits and a water tube) through which water is pumped on call by the water-heating temperature sensor. One refrigerant circuit is for the discharge gas from the compressor, which always passes through the heat exchanger; the other circuit is for the low-pressure liquid-vapor that is evaporated in the heat exchanger during the defrosting mode.

In the winter, the water-heating heat exchanger acts as a desuperheater and a partial condenser, depending on the capacity required for space heating. In the summer, the water-heating heat exchanger recovers waste heat from the space-cooling operation by desuperheating or fully condensing the discharge gas from the compressor, depending on the load. When neither space heating nor cooling is required, the heat exchanger heats water by condensing the compressor discharge gas.

Figure 1 The integrated heat pump system employs a tube-in-tube heat exchanger (with two refrigerant circuits and a water tube) through which water is pumped on call by the water-heating temperature sensor.



The six main operating modes of the system are space heating, space and water heating, water heating, space cooling, space cooling and water heating, and defrosting. In addition, fan operation occurs at various times during these modes, and operation of the supplemental electric resistance elements in the indoor fan/coil unit and the water heater tank also can occur. In general, the upper element of the water heater tank is not controlled by the heat pump control logic, so the customer can set hot water temperatures higher than the 130°F (54°C) produced by the heat pump.

Technical performance

Table 1 gives the integrated heat pump system's heating seasonal performance factor (HSPF) and its seasonal energy-efficiency ratio (SEER), the standard efficiency rating measures used in the United States for heating and cooling, respectively. To put these measures in the larger perspective of the technology available on the U.S. market today, consider that the sales-volume-weighted average HSPF for heat pumps sold in the United States in 1988 was 6.85, and the average SEER was 9.1.

Because the integrated heat pump system is new, there is as yet no official industry or

Table 1
CAPACITY AND EFFICIENCY RATINGS

Operating Mode	2-Ton Unit	3-Ton Unit
Heating		
Capacity at 47°F (Btu/h)	24,800	36,000
Capacity at 17°F (Btu/h)	15,800	21,400
HSPF for Region IV (Btu/Wh)	8.8	9.0
Cooling		
Capacity at 95°F (Btu/h)	24,900	37,000
SEER (Btu/Wh)	13.4	14.0
Water heating		
Capacity (Btu/h)	19,800	20,800
Coefficient of performance	2.6	1.9

Table 2
SYSTEM COMPARISONS OF ANNUAL OPERATING COSTS FOR THREE LOCATIONS

System	Atlanta, Georgia	Columbus, Ohio	Portland, Oregon
Conventional heat pump with electric water heater*			
Heating (kWh)	6,038	12,173	8,431
Cooling (kWh)	4,876	2,605	1,026
Water heating (kWh)	5,370	5,459	5,469
Operating cost ($)	1,174	1,147	822
Gas furnace with electric air conditioner and gas water heater†			
Heating (therms)	511	864	736
Heating fan (kWh)	334	578	475
Cooling (kWh)	4,620	2,470	973
Operating cost ($)	846	885	712
Integrated heat pump			
Heating (kWh)	4,734	10,083	6,572
Cooling (kWh)	3,295	1,771	706
Water heating (kWh)	2,938	3,355	3,341
Operating cost ($)	791	862	585

*Heat pump HSPF of 6.85 and SEER of 10, water heater efficiency of 95%.
†Furnace efficiency of 92.2%, air conditioner SEER of 10.5, water heater efficiency of 65%.

government-approved rating method that accounts for water heating efficiency when that function is integrated with space conditioning. Moreover, it is difficult to allocate power consumed by the compressor and fans to space conditioning and water heating when both are occurring simultaneously. Therefore, the water-heating coefficient of performance given in Table 1 is only an approximate measure of the efficiency of water heating and applies to that part of the operating cycle when the system is running to heat water only.

The high efficiency of the heat pump means that its power demand during peak heating or cooling load hours is considerably lower than that of the average heat pump or air conditioner on the market today. For utilities with heating or cooling load management programs, the heat pump incorporates a demand-limiting control option. Upon receipt of an appropriate signal from the utility's load-control receiver switch at the customer's premises, the heat pump compressor is limited to 80% of the speed at which it would otherwise run to meet the heating or cooling requirements of the house. The resistance elements in the water heater are disabled, allowing the water temperature to drift down a maximum of 5°F (3°C). If the system is in the heating mode, the demand-limiting control also deenergizes the first stage of supplemental resistance heating; however, the higher stages are allowed to operate when called for by the thermostat. Laboratory tests and analyses indicate that the load reduction attributable to this control feature is approximately 0.4 kW/ton during peak heating periods and 0.3 kW/ton during peak cooling hours.

Market and economic analyses

Market prospects for the integrated heat pump have also been evaluated. By 1988, shipments of unitary (factory-assembled) heat pumps had grown to approximately 835,000 per year. About 85% of the units shipped in 1988 were residential units, and the rest were commercial. Of the residential heat pumps that were shipped, new single-family and multifamily construction absorbed about 54%, whereas replacements and conversions accounted for 31%. On the basis of earlier mar ket surveys conducted in the course of this project and for a previous DOE project, it is estimated that about 8% of the new construction market and 35% of the replacement market would be accessible to the integrated heat pump if the payback period for the first-cost premium can be kept to less than five years. This translates to a market potential of 108,000 units per year for which the integrated system and other high-efficiency heat pump products would compete.

Table 2 compares the operating cost of the integrated heat pump system with those of (1) a conventional heat pump combined with electric resistance water heating, and (2) a high-efficiency gas furnace combined with electric air conditioning and gas water heating. Locally prevailing electricity and natural gas prices were used in the comparisons. The integrated system offers annual operating cost savings of 25–33% compared with the all-electric system and 3–18% compared with the gas and electric system.

Field demonstration

To gain operating experience with the integrated heat pump, 10 prototype units were installed in occupied residences in January 1987 and were continuously operated until late 1989, when they were replaced with production model units. Data were taken every 15 minutes by a computer at the field site and were transmitted every 24 hours to a central computer at Carrier's R&D laboratory in Syracuse, New York. The data were then reduced and analyzed every morning to determine if there were any field operating problems that required attention.

During the past year the occupants of the test homes have generally been very satisfied with the heat pumps' performance and very pleased with their quiet operation. Not only were the prototype units replaced with production models, but the number of field test sites was expanded to 31 homes. On the basis of market acceptance, future product improvements may include ice storage and compatibility with home automation systems.

Production status

The advanced heat pump, tradenamed HydroTech 2000, began production in July 1989. A pilot run of 30 units was conducted earlier in 1989 for final testing and rating purposes, and those units were sent to utilities participating in the EPRI field test program and to selected Carrier distributors. HydroTech 2000 is now available in 2- and 3-ton (nominal cooling) capacities, with 5-ton units to follow later this year. The product carries the usual UL and CSA (Canadian Standards Association) certifications and is listed in the Air Conditioning and Refrigeration Institute's directory of unitary heat pump equipment.

Recognizing that the electronic drive and integrated water-heating technology is new to the residential and light-commercial air conditioning field, EPRI and Carrier have conducted a staged product rollout, preceded by extensive training for dealers and distributors and briefings for utilities. In the first phase, eight Carrier distributors (located in the Southeast, the Midwest, and the Pacific Northwest) introduced HydroTech 2000 through selected dealers. In the second phase, now in progress, 27 additional Carrier distributors are marketing the unit. The first two phases together involve about two-thirds of the Carrier distributor organization. Nationwide distribution will follow later this year.

Transportation Program

The Electric G-Van

by Gary Purcell, Customer Systems Division

EPRI is sponsoring two promising electric vans, the G-Van and the Chrysler TEVan. The electric G-Van (Figure 1), based on the General Motors Rally, is the product of cooperative activity involving EPRI, GM, Chloride EV Systems, and Magna International. G-Van specifications include the following: lead-acid battery, power steering and brakes, single-speed transmission, off-board charger, 1550-pound payload, 256-cubic-foot cargo area or space for five passengers, 125-inch wheelbase, 60-mile urban driving range per charge, 52-mph top speed, and acceleration from 0 to 30 mph in 13 seconds.

Limited production is expected to begin in 1990, and 500 vehicles are planned for the first year They will be the first full-production electric vehicles offered for public sale in the United States since the early 1900s. GM supplies the van's body and chassis; Chloride EV Systems supplies the power train and batteries; and Magna International assembles the electric vehicles through its subsidiary, VEHMA International.

In May 1987, EPRI contracted with Cars and Concepts to assemble three proof-of-concept vehicles, with cofunding from Southern California Edison. In October 1987, after a feasibility study was performed, the three vehicles were constructed. On the basis of this concept demonstration, EPRI issued a request for proposal, and in July 1988, VEHMA was selected to bring the vehicle to production.

Phase 1 of the VEHMA contract covered production engineering, including the redesign of the van for assembly-line production and the calculation of a preliminary cost estimate. This phase was completed in December 1988. Phase 2, which is scheduled for completion in May 1990, includes a test program, setup for production, and a final cost estimate.

Before a vehicle can be offered for public sale, the federal government requires that it be certified; that is, the manufacturer must sign a document indicating that the vehicle has passed certain federal government crash tests. In addition, the industry itself typically performs other tests (e.g., for dust intrusion

Figure 1 The electric G-Van is based on the body and chassis of the General Motors Rally. The G-Vans are being assembled as electric vehicles by Magna International through its subsidiary, VEHMA International. They are scheduled for production in 1990.

ABSTRACT *The electric G-Van will go into commercial production in 1990. Preparation for production has involved several steps, including the assembly of 3 proof-of-concept vehicles, 8 test vehicles, and 25 prototypes. VEHMA International will assemble the vans, General Motors will supply the bodies, and Chloride EV Systems will provide the power trains. It is expected that the electric G-Van will fill a clear market demand for clean, reliable transportation.*

and water leakage) to ensure the overall quality of the vehicle. VEHMA built eight test vehicles to satisfy these requirements. All federally mandated tests were completed on these vehicles by January 1990, and all industrial standards tests are to be completed by production startup.

In mid-1989, VEHMA began to set up for assembly production. It selected the facility and began to organize the personnel and acquire tooling.

In parallel with production engineering, VEHMA built 25 prototype G-Vans, which were purchased by EPRI and various utilities. These prototypes were assembled according to production-design specifications and put into service in order to obtain an early indication of possible real-world problems.

Sales and service of the production vehicles will be handled by selected GM fleet dealers. Any early problems with the power train will be serviced by VEHMA in regional centers. However, GM dealer personnel will be trained so that eventually the dealers will provide full service. Since electric vehicles contain fewer and simpler components than gasoline vehicles, they are expected to have fewer maintenance problems and to be highly reliable.

The challenge during the next three to five years is to introduce the electric vehicle in the commercial market. This is a step-by-step process that is initially dependent on utility interest and support to seed the market and improve the products. The necessity of coping with environmental pollution is the strongest incentive for the use of electric vehicles. Beyond that is the economic incentive, which for utilities is an increase in off-peak electricity sales. For each electric vehicle, this increase is equivalent to off-peak sales to 1.5 U.S. residences.

As more vehicles are produced for the market, their costs will come down. Because of lower maintenance requirements and cheaper fuel, the life-cycle costs of electric vehicles will eventually approach those of internal-combustion vans. The electric vehicle market will initially be concentrated in commercial vans. When smaller cargo and passenger models go into regular production, however, the market will broaden to include the large personal van and auto market.

Component Reliability

Minimizing Vibrations in Fossil Fuel Generating Units

by Thomas McCloskey, Generation and Storage Division

Vibration problems in rotating machinery are a major contributor to forced or unplanned maintenance outages in fossil-fuel-fired power plants. Turbine blade failures, many of which are caused by vibration-related fatigue stresses, are the leading cause of steam turbine outages for large fossil fuel plants in the United States, costing utilities more than $235 million annually. Conversion of large units to cycling operation has also increased blade failures.

Lateral and torsional vibrations in turbines, generators, pumps, fans, and motors cost utilities more than $170 million annually. Rotor dynamic instability and hydrodynamic forces induced by the working fluid and by coupled mechanical-hydraulic interactions cause vibrations that can damage rotor, bearings, and seals and adversely affect foundation, piping, and ductwork.

EPRI has developed a series of troubleshooting tools to help utilities determine the root causes of turbine blade and other rotating machinery failure. With this knowledge utilities can identify the costs and benefits of possible solutions and apply an overall strategy of reducing repair costs, increasing availability, and improving rotating machine life.

Turbine blade vibration

In conjunction with Stress Technology, EPRI has developed an interactive code called BLADE (blade-life algorithm for dynamic evaluation) to provide utilities with an independent means of analyzing and troubleshooting vibration-related blade failures (RP1856-7). The code uses finite-element techniques to analyze the fundamental causes of blade failure, thus helping utilities make the most cost-effective redesign and repair decisions. By predicting remaining blade life, the code can also help optimize inspection intervals and ensure safe, reliable plant operation.

BLADE constructs a dynamic model for a blade group by mathematically replicating a single-blade model. The group model then uses turbine stage dimensions and operating characteristics to calculate vibration characteristics, including natural frequencies and mode shapes, and forced responses to the applied excitation spectrum.

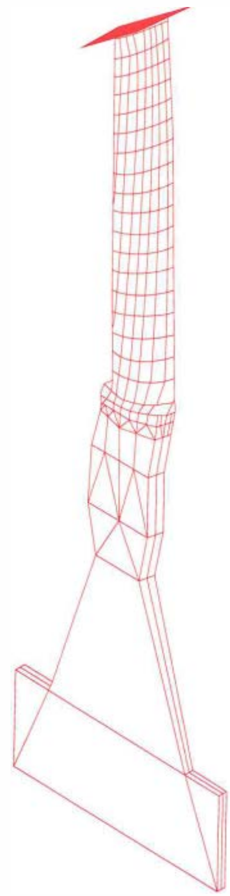
Using the local-strain approach to fatigue analysis, BLADE predicts when cracks will occur in high-stress regions, such as the blade root fillet. The method registers alternating stresses of various amplitudes and accumulated information on their damage in order to predict the time of failure. Southern California Edison was one of the first utilities to apply the BLADE code. SCE estimates that over 95% of the steam-induced failures in the last two rows of its low-pressure steam turbines have resulted from fatigue caused by tangential-mode vibration. SCE had already used harmonic shrouding and, later, continuous harmonic shrouding (CHS) to prevent tangential-mode failures on 16-inch blades at its Huntington Beach Unit 4 L–1 stage. In 1985, it considered using CHS on longer blades (28.5 inches) at Huntington Beach Unit 2.

Using BLADE, SCE was able to evaluate the stresses in the original short-arc shrouded blades in Unit 2 and predict the life expectancy of the blades with the CHS modification. BLADE indicated that the design would not introduce new, failure-inducing stresses, and SCE successfully installed the modified design (Figure 1). The resulting savings are estimated to be $1.28 million. SCE has now identified 111 additional rows of constant-speed main turbine blades in its system that can benefit from this modification in the foreseeable future.

TVA and Pacific Gas and Electric have also used the BLADE code to analyze the potential advantages of replacing conventional stainless steel low-pressure blades with titanium alloy blades at several of their fossil plants (*EPRI Journal*, November 1985, p. 22). An enhanced, IBM PC version of BLADE will help utilities analyze and troubleshoot high-temperature blades for use in steam and gas turbines and address such problems as creep fatigue and hot corrosion. Development of a comprehensive blade manual for inspection, failure-cause analysis, and repair/refurbishment is also under way and will be available in 1991 (RP1856).

As an extension of this analytical capability, EPRI has also developed a system for on-line measurement of dynamic blade stresses, natural frequencies, and mode shapes (RP1856-7). In STEMS (stress telemetry monitoring system), strain and pressure gauges attached to turbine blades transmit data to a rotating FM antenna/transmitter. The signals are then transmitted to a stationary antenna/receiver for processing by spectrum analysis and the BLADE code. STEMS helps utilities predict the root causes of blade cracking and evaluate alternative design, operating, and repair options. SCE used STEMS to evaluate the CHS application at its Huntington Beach station and to compare actual data with BLADE-predicted values. The test results validated the BLADE code and showed relatively small dynamic stresses under the full range of operating conditions. Future EPRI work in the area of in situ blade vibration monitoring will include the investigation of nonintrusive laser-

Figure 1 BLADE code finite-element model of a single bladed disk. This model was used as the basis for retrofitting a continuous harmonic shroud on a Unit 2 turbine generator at Southern California Edison's Huntington Beach station.



ABSTRACT *EPRI has developed a number of tools that allow utilities to independently assess the root causes of vibration problems in rotating machinery. These computer codes and guidelines to help utilities analyze turbines, generators, motors, pumps, fans, and other plant machinery are able to reduce outages, minimize repair costs, and extend component life. These technologies will go far toward making better use of rotating machines and improving future designs.*

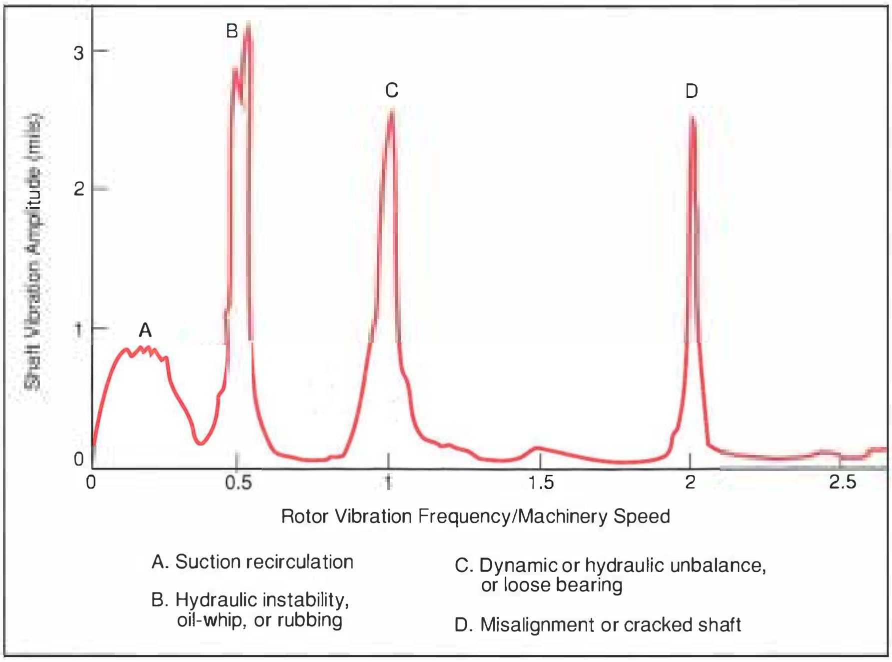


Figure 2 Frequency spectrum of typical feedpump vibration problems. The ratio of pump vibration frequency to running speed can be used to determine the major causes of machine failures. A frequency/speed ratio of 2, for example, could indicate a misalignment or cracked shaft.

based systems for measuring axial and torsional vibration.

Rotor and bearing vibration

The combination of aging rotating machinery and high reliability demands has elevated the importance of vibration monitoring of main turbine generators, auxiliary turbines, motors, pumps, and fans in power plants. EPRI research in this area has resulted in two key tools, developed by Mechanical Technology: FEATURE (finite-element analysis tool for utility rotordynamic evaluation) and the companion code COJOUR, a computer program for analyzing large turbine-generator bearings.

FEATURE determines the critical speeds, overall stability, and vibration response of rotating machinery, such as steam turbine generators, drive turbines, combustion turbines, pumps, fans, and motors. The second release of the code adds a static alignment option for bearing-load computation and a number of output upgrades. A multilevel analysis capability allows accurate modeling of machines that have several concentric rotors or flexible housings, such as long, slender vertical pumps. To effectively model rotor systems using analytical tools such as FEATURE, coefficients representing bearing stiffness and damping characteristics are needed. Unfortunately, such information is generally unavailable for large bearings like those in turbine generators.

Addressing this need, EPRI developed COJOUR to analyze fixed and tilting-pad fluid-film bearings. COJOUR incorporates models of heat generation, turbulence, and inlet groove oil mixing, and it accommodates complex variations in geometry, such as overshot grooves and lift pockets.

FEATURE and COJOUR produce graphics output, including plots of the rotor and bearing models, bearing-pressure profiles and rotor mode shapes, deflected shapes, and orbits. One graphics option interfaces with the Tektronix IGL package to provide output on that manufacturer's equipment. A second option makes all graphics output accessible on IBM PC and compatible microcomputers.

A number of utilities have applied the FEATURE/COJOUR package successfully to a variety of rotating equipment. For example, users have determined optimal locations for vibration sensors; developed an understanding of the behavior of complex, highly instrumented vertical pumps; and analyzed several mechanical-drive turbines, boiler feedpumps, and fans. Potential applications include determining the effects of turbine misalignment, controlling fan critical speeds, solving hydraulic instability problems, understanding the output of monitoring systems, and evaluating the dynamic performance of replacement rotors and bearings.

In a recent application of FEATURE/COJOUR to horizontal pumps conducted by the Machinery Vibration Institute of Case Western Reserve University, excessive vibration was minimized in a boiler feedpump at Delmarva's Indian River plant. COJOUR and FEATURE were used in a two-phase process to compute journal bearing dynamic properties and rotor vibration, respectively.

In the first phase, a FEATURE/COJOUR computer model was developed and calibrated to replicate the reported feedpump rotor vibration characteristics. In the second phase, this calibrated model was used to perform various "what if" studies on journal bearing modifications. Results showed that replacing the existing pump inboard journal bearing with a pivoted-pad journal bearing would help solve the vibration problem.

In addition to the application of FEATURE and COJOUR to boiler feedpumps, EPRI is developing a comprehensive series of guidelines that cover operation, maintenance, and repair/refurbishment of these pumps. Typical hydraulically induced vibration problems in high-speed, high-energy-input boiler feedpumps can be divided into several categories on the basis of their vibration frequency and other operational and design parameters (Figure 2).

These guidelines have been successfully used in several utility applications. At two identical 800-MW units operated by TU Electric, boiler feedpump hydraulic instability in the range of 450–500 MW severely restricted use of the units for load following and frequency control. Using guidelines developed by Energy Research & Consultants, TU Electric learned that severe vibrations similar to those its pumps were experiencing can be induced by an improper geometric relationship between the pump impeller and the diffuser. With modifications to the first and subsequent stages, the pumps now operate satisfactorily over the entire load range. Over 50 centrifugal pumps have been modified to date; the result has been over $17 million in savings to TU Electric.

At the Mercer station of Public Service Electric & Gas (PSE&G), several boiler feedpumps have exhibited severe vibration-related problems, including rotor dynamic and hydraulic instabilities at reduced load, and have required increased maintenance because of excessive internal wear. On the basis of the EPRI guidelines, several recommendations were made to attempt to solve these problems. For example, the clearances between impeller and diffuser were modified, and anti-swirl slots were machined in the balance disk bushing to reduce the rotor dynamic and hydraulic instability problems. By implementing these and other EPRI recommendations on one of its boiler feedpumps, PSE&G improved overall pump reliability, increased pump capacity, reduced the subsynchronous vibration range, and decreased maximum shaft vibration.

Field troubleshooting tools such as BLADE, STEMS, FEATURE, and COJOUR, and guidelines like those developed for boiler feedpumps, can enable utilities to take the lead in solving vibration-related problems with their rotating machinery. The result will be increased plant availability, reduced maintenance costs, and improved component life.

Air Quality Research

Human Perception of Visibility

by Peter Mueller and James Davis, Environment Division

ABSTRACT *EPRI research efforts have resulted in important scientific advances relating to the role of atmospheric aerosols in the human perception of visibility. A new instrument for quantifying human visual perception provides a tool for evaluating the current scientific and legal definition of visibility impairment. Moreover, a novel computer model now offers a means for enhancing our understanding of the complex interactions between atmospheric aerosols, radiative transfer, and human psychophysics—factors that determine how changes in haze level influence visual air quality.*

Visibility degradation due to air pollution is a growing public concern, especially in areas possessing exceptional scenic resources. National parks and monuments, designated in the 1977 Clean Air Act Amendments as Class I federal areas, are considered to be particularly important in this respect. The impacts of concern are layered discoloration of the landscape by plumes and impairment of vista contrasts by uniform and layered hazes. Current air quality regulations include provisions for evaluating, preventing, and remedying existing and future impairment of visibility in Class I areas. Moreover, proposals to strengthen and expand these provisions, and lawsuits seeking more stringent enforcement by the EPA, continue to focus attention on the issue.

Because thermal power production releases sulfur dioxide (SO_2) and nitrogen oxides (NO_x)—some of which end up in atmospherically formed particles—emissions from utility operations could contribute to the occurrence of atmospheric hazes. The origins of such hazes, however, depend on factors such as weather, humidity, atmospheric chemistry, and emissions from a wide variety of natural events and human activities. In addition to the need to quantify the relative importance of these factors under given circumstances, there is a need to relate the alterations in atmospheric particles to changes in human perception of vistas. This leads to the problem of how to characterize human perception objectively and quantitatively.

EPRI's Environment Division has undertaken a comprehensive, multidisciplinary research program to provide the knowledge and tools for evaluating the relationship between utility operations and layered and uniform hazes (at both local and regional scales). The approach to the problem has four steps:

- Atmospheric emissions transport and chemistry—relating emissions sources to atmospheric aerosol properties and concentrations

▫ Atmospheric aerosol optics and radiative transfer—relating atmospheric aerosols to the transmission of light between a scene and an observer

▫ Psychophysics—relating changes in light intensity and color to human visual perception and aesthetic quality judgments

▫ Valuation—relating aesthetic value to economic value

Sources of haze-producing emissions can thus be related quantitatively to perceived visibility and the corresponding socioeconomic implications. This approach can guide researchers and inform policymakers and utility managers on the essential aspects of the visibility impairment issue.

The first step, finding the link between atmospheric aerosols and emissions, is also a component of research on other issues, such as acidic deposition and compliance with air quality standards. All these issues require knowledge of atmospheric physics and chemistry, which has been enhanced by EPRI's sponsorship of theoretical, laboratory, modeling, and extensive observational (field) studies. Integrating such knowledge informs those concerned about the relationships between emissions, atmospheric processes, and air quality.

This update addresses the second and third steps, which involve human perception—the element that has made visibility impairment difficult to understand, describe, and quantify. The fourth step, quantifying the relationship between aesthetic quality and economic value through refined valuation methods, is also ongoing (see the research update on p. 50 of this issue).

Accurate optical instruments have been available for many years for directly measuring intensities and wavelength distributions of light. Only recently, however, has the technology been applied to the environmental (as distinct from navigational) visibility impairment issue. Two essential applications are in relating the physical and chemical properties of particles to the atmospheric transmission of light, and routinely monitoring visual air quality. The technology can also be used for establishing the physical characteristics of the light incident on the eye and relating this to human observations, which are more subjective.

One widely used approach is based on color standards developed for matching paints and cloth by the Commission Internationale de l'Eclairage (CIE). In addition to color, contrast and visual range are central to human perception. All of these factors are influenced by the complex interaction of ambient lighting conditions, the observer's experience and visual acuity, the scene content, and the particles in the haze.

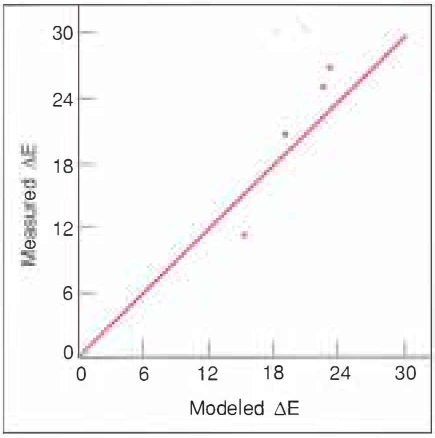
Recently, EPRI-sponsored research has made important advances that relate aerosols in the light path to subjective judgments, specifically in calculating human perception of vistas and in measuring how changes in atmospheric aerosols alter human perception of colors and color differences.

Visibility perception simulation

Many factors must be considered to fully account for perceived colors and color differences in vistas: the concentrations, size distributions, shapes, and light-scattering and -absorption properties of major classes of atmospheric particles; the intensity and color of light (radiance) reflected from individual scene elements; the illumination of the light path from all directions; the scattering of light by particles in the light path; the observer's distance from the scene elements; the position of the sun in relation to the viewing direction; and the psychophysical response of the human eye-brain system. All these factors have been accounted for in the landscape color visibility model (LCVM), a unique computer code developed for EPRI by A. Clyde Hill and his colleagues at the University of Utah Research Institute. This model now makes it possible to simulate the way people perceive vistas.

The LCVM employs a mechanistic representation of current radiative transfer theory to calculate the intensity of light as a function of wavelength reaching the observer along the light path from the direction of dominant scene elements. The model can be used to simulate uniform hazes, layered hazes, and plumes by dividing heterogeneous light paths into homogeneous segments that can then be modeled in sequence. The LCVM is divided into two modules, which can operate separately or in concert. The phase module first calculates the scattering properties of the atmospheric gases and particles in the light path as a function of aerosol characteristics, meteorological conditions, scattering angles, and wavelengths. The main module combines this information on phase functions with scene characteristics and employs radiative transfer theory to calculate the light reaching an observer from the direction of each scene element.

Figure 1 Comparison of measured and modeled color differences (ΔE), i.e., contrast, on different days at the Grand Canyon's Havasupai Point, showing match to a 1:1 line.



As part of the study, observations were obtained at the Grand Canyon in 1984 and 1985 to test and improve the data collection methods needed for initiating the model calculations and for relating the output to opinions provided by park visitors and a panel of residents. One set of field measurements was used to test the ability of the LCVM to simulate landscape colors and color differences for typical scenes using actual data. A comparison of modeled and measured values for color differences (a model output related to contrast) resulted in a virtual 1:1 correlation (Figure 1).

After successful testing, the first application of the model involved evaluating the sensitivity of perception parameters (hue, purity, and color differences) to observational circumstances. The most important factors turned out to be target distance, sun angle, particle concentration, and particle type. For example, the LCVM-simulated color difference decreases with decreasing sun angle and with increasing target distance, particle concentration, or percentage of fine particles in the aerosol.

When comparing these field measurements and model results with human judgments of scenic quality, it was found that the survey techniques previously employed by others biased the subjects' reporting of aesthetic experience by drawing their attention to the influence of aerosols. Subsequently the principal investigators explored an innovation for obtaining unbiased observer opinions by measuring the subjects' viewing times and aesthetic quality rankings for 8- by 10-inch backlit color transparencies (instead of projected 35-mm slides). Ranking the images was found to be superior to using a subjective rating scale unfamiliar to the subjects. It was discovered that the time required to rank a vista was inversely proportional to the quality ranking, implying that viewing time can be a direct indicator of aesthetic quality.

Measuring visibility perception

Concurrent with the development of the landscape color visibility model, Ron Henry and Luis Matamala at the University of Southern California developed a new device for directly measuring human perception of colors. The device was used to appraise the applicability of commercially employed color theories and technologies (including the CIE standards) to visibility assessments. A prototype of this visual colorimeter for atmospheric research (VICAR) was also used in the vista studies by A. Clyde Hill.

The VICAR (Figure 2) is an asymmetric, binocular color-matching device through which an observer views, in the instrument, an adjustable color spot with one eye—while the other eye views the ambient scene. It is asymmetrical in that each eye is adapted to different lighting conditions; the VICAR eye is adapted to a standard white background, while the other eye is adapted to ambient conditions. Using potentiometer dials, the viewer adjusts the instrument's color spot to match what is perceived in the naked-eye view in terms of the quality, color, and brightness of a scene element of interest. The instrument then registers quantitative CIE color indices of human perception, which can be compared with direct CIE index measurements by using standard optical instruments, such as telespectrophotometers.

Although colorimeters have long been used in color-vision research, they were not used specifically in atmospheric visibility studies until 1984. All colorimeters at that time were designed to be operated with indoor lighting intensities, over short distances, and under controlled laboratory conditions.

Unlike earlier colorimeters, the VICAR is able to match the high luminances found outdoors, producing luminances of several thousand footlambert. The device is also unique in its ability to measure the appearance of one color as seen through other, semitransparent colors. The new VICAR requires only one ordinary 110-Vac, 8-A power circuit to operate and is easily portable, measuring 21 inches long, 10 inches wide, and 16.5 inches high and weighing 44 pounds. Furthermore, it is rugged and capable of withstanding a wide range of temperatures (−10°C to 35°C) and other environmental conditions, enabling it to maintain stable calibration over several weeks in the field.

Tests of a prototype VICAR by A. Clyde Hill and his colleagues during their 1984–1985 field study generally found excellent agreement between the multiple-observer VICAR matches and both modeled (LCVM) and measured (spectrophotometer) CIE indices for color purity and hue. The VICAR performed equally well for targets at various distances and under different viewing conditions. Hill's group concluded that the CIE system was indeed adequate for specifying colors and color differences in visibility measurement and modeling studies.

A more recent field study using a newer-model VICAR was undertaken by Ron Henry in 1988 (also at the Grand Canyon) to further examine the use of CIE chromaticities and

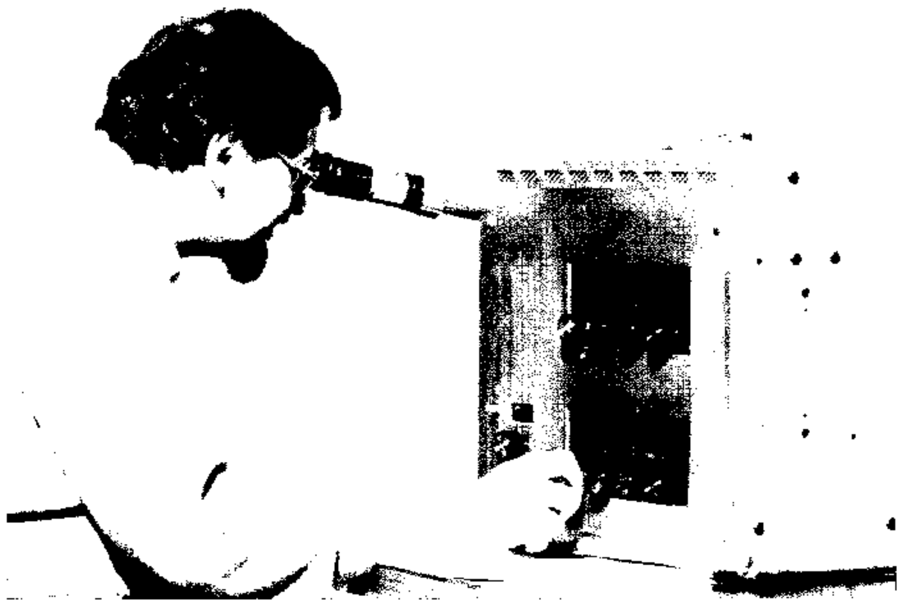


Figure 2 **Ron Henry demonstrates the use of the visual colorimeter for atmospheric research (VICAR) by viewing the Los Angeles skyline through the haze from atop the engineering building at the University of Southern California. The potentiometer dials are used to adjust the instrument's internal color spot (viewed through the eyepiece) to match the scene colors as perceived in the naked-eye view. On the basis of the color matches, the VICAR records color indices to quantify human perception of colors.**

color difference formulas in visibility modeling and research.

As in the previous study, the experimental evidence (this time from a single observer) showed that the standard color calculations worked very well for nearby objects. Contrary to the Hill results, however, the CIE system failed to predict the appearance of distant natural objects. Color differences between small, distant objects, as measured with the VICAR, were almost a factor of 10 greater than those recorded by means of a spectrophotometer. It remains to be determined, by means of other field tests, whether this discrepancy is real, and if so whether it could have been caused by differences in target-area resolution for the VICAR and spectrophotometer methods, which could have resulted in a "distance effect."

On the other hand, the differences between the perception-based (VICAR) and spectrophotometric measurements could—according to a speculative hypothesis—stem from a possible inherent discounting by the human eye-brain system of the role of path luminance on the color of distant objects.

If true, this reasoning would suggest that distance may not be as important to visibility perception as the LCVM simulations have indicated, and that substitution or modification of the CIE system in such models may be necessary. It would also challenge the current use of photographs and computer-generated images—which cannot yet account for a three-dimensional distance effect—as a basis for establishing the economic value of changes in visibility. Not surprisingly, these implications are causing debate among visibility professionals and promise to guide the direction of future research.

Air Quality Research

Measuring the Value of Improved Visibility

by Victor Niemeyer, Environment Division

Releases of sulfur dioxide (SO_2) by electric utilities and other sources can lead to the formation of sulfate (SO_4) in the atmosphere. Because much of that sulfate is in the form of fine particles (1–10 micrometers in diameter), it is one of the many factors that contribute to light scattering, which degrades visibility (e.g., visual range, contrast, coloration). SO_2 emissions from a wide variety of sources can contribute to visibility reductions on a regional basis, depending on wind velocity, humidity, and various aspects of atmospheric chemistry. The emissions from one particular source can also contribute to visibility reductions on a local basis.

Visibility is regulated under sections of the Clean Air Act that require the weighing of costs and benefits in determining the need to control emissions. Partly in response to that requirement, several studies over the last 15 years have attempted to estimate the dollar value of visibility changes. Some of these studies have claimed large benefits from improved visibility resulting from reductions in SO_2 emissions. EPRI and others, however, have identified serious methodological shortcomings in these pioneering studies that limit their useful application in policy debates.

For this reason EPRI has been conducting a systematic effort to understand the strengths and weaknesses of methods for valuing visibility improvements and to further advance the state of this science. The EPRI effort has drawn on the skills of a multidisciplinary team from the variety of fields involved in valuing visibility—psychology, economics, sociology, and decision analysis. The focus has been to advance the methodology of visibility valuation rather than to obtain specific estimates of values for a particular policy debate.

Estimating the value people attach to visibility improvements is a difficult problem, primarily because visibility is not a commodity that has a market-determined price. It is, instead, what economists call a public good—something that provides value to individuals and the community but is not bought and sold. Some public goods (e.g., highways, police and fire protection, flood control, public health and weather services) are provided through government action, but others, including air and sunlight, are provided by nature. Because these goods are not traded in markets, sophisticated methods are needed to infer their values.

There are two general approaches for attempting to value public goods. The first is the indirect approach of observing actual behavior exhibited by people and then inferring the value of a good from those observations. An analyst, for example, can assess the value of a national park by considering the amount of money people pay to visit it, including park entrance fees, the value of the visitors' own time, and travel costs. The reasoning is that the value of the park must be at least as great as what people spend in getting there or they will simply not go.

The indirect approach has proved unreliable for visibility valuation, partially because of the difficulty of isolating visibility from other attributes that affect value. In one study, an attempt was made to assess the value of visibility through a hypothesized effect of visibility on housing prices. Consistently separating visibility from other factors affecting housing prices, however, proved too difficult to permit a precise and reliable estimate of the dollar value of visibility.

Indirect methods also fail to take into account "existence values," which can be an important aspect of public goods. A person on the East Coast may value the fact that a place such as Yellowstone National Park exists and is preserved in a pristine state (without visibility impairment), even if that person never goes there.

A second general approach is to ask people directly what they are willing to pay for a public good. Contingent valuation (CV) is the most widely used technique for doing this in the area of visibility valuation. In the CV approach, a sample population is surveyed through personal or mail interviews and asked directly how much they would be willing to pay for improved visibility. The answers, which are contingent on the description of the improvement, can then be analyzed.

There are numerous points where errors or bias can generally enter the contingent valuation process. The analyst must define a hypothetical transaction that precisely describes the visibility improvement that people can buy. The improvement must be illustrated in a way that the respondents will understand. Sociologists have discovered that people often interpret survey questions in unexpected ways, especially when they are unfamiliar with the context of the survey.

The hypothetical transaction must be framed in a way that encourages the respondents to take the question seriously. If it is not, they may say they are willing to spend unrealistically large amounts for the public good because they do not view the dollars they spend as real.

In presenting the hypothetical transaction to be valued, care must be exercised to avoid giving clues to people about what answer is expected by the researchers. Psychologists have discovered that survey respondents unconsciously seek such clues even when they are unintended by the researcher.

Research has demonstrated that there are different values held by subgroups within society. These subgroups cannot be forced into a single model of consumer benefit.

At the analysis stage, it is difficult to separate zero bids that denote no valuation from zero bids that denote a protest over the interview process or nonacceptance of the hypothetical transaction.

For visibility, there are additional complexities in inferring the values of changes. One is that although people are generally familiar with the concept of reduced visibility, it is hard to measure and define in meaningful ways to nontechnical audiences. Using scenic vistas to show the possible changes may bias valuations upward. On the other hand, more common vistas (e.g., city streets) may not cover enough distance for people to be able to perceive the changes in visual range; consequently, some studies have used visibility improvements of 100–200% in valuation interviews rather than the 10–20% improvements (for a few days per year) that can realistically be anticipated from policy options for controlling SO_2. In addition, specialists in visual aesthetics have discovered that subtle color and scenic variations in photographs can dominate the aesthetic quality of real vistas, as well as photographic presentations of those vistas.

ABSTRACT *Utility releases of sulfur dioxide to the atmosphere can degrade visibility. Some attempts to estimate the dollar value of visibility changes have claimed large benefits from improved visibility attributable to reductions in SO_2 emissions, but the studies that generated these estimates have suffered from serious methodological flaws. Improved understanding and methods are needed to ensure that regulators and policymakers have the best information available when assessing the costs and benefits of controls. In response, EPRI has been conducting a systematic effort to further advance the state of this science.*

Second, in many cases visibility is affected by meteorology more than by emissions. This makes it difficult to represent realistic changes because the changes may not be easily perceived at the conscious level. A reduction in emissions may lead to slight improvements for many days a year that are hard to notice or may lead to easily noticeable changes but for only a few distinct weather day types. This adds to the challenge of ensuring that the respondent understands the contingency being valued.

Third, when people see examples of poor visibility, they may associate the haze with adverse health effects, even if there are none or if the health effects are being assessed directly in another part of the analysis. Consequently, their estimates of visibility values may include additional values for perceived health benefits from the clearer air. This effect biases the estimated value of visibility improvements upward.

Previous studies using contingent valuation to quantify the value of visibility improvements have suffered from the problems and complexities described above. In part, this is because contingent valuation covers a multitude of research disciplines, such as psychology and economics, and researchers have not integrated the results from these disciplines when creating the study and interpreting the results.

EPRI research

The research being sponsored by EPRI addresses several areas related to contingent valuation of visibility benefits. First, the researchers are specifically trying to develop

Figure 1 Robert Mitchell interviews a CV respondent to elicit her responses on the value of improved visibility. The respondent is reading a card that describes a specific emission control program. Ten different program cards are used. During the interview, Mitchell will ask the respondent whether she would vote yes on a referendum for the program and, if so, how much she would be willing to pay before she would switch her vote.

survey design and implementation methods that correct some of the problems with previous studies. A second effort has been to create and widely distribute a preliminary psychological framework for evaluating the responses people make to CV questions. Third, work is ongoing to advance a more reliable theory of statistical analysis for CV survey response data. Fourth, computer-generated photographs are being created to simulate changes in visibility conditions at a given vista. Using actual photos limits the degree of variation in visibility that can be shown to the survey respondents, and with actual photos it may not be possible to realistically demonstrate the visibility improvements that can be achieved.

The EPRI work is being conducted by a multidisciplinary research team to ensure that knowledge from all relevant fields is incorporated into the project. A group of project advisers with representatives from utilities, the EPA, the National Park Service, and the technical community is providing ongoing guidance to the project. The central point of focus for much of the work is the design and testing of a contingent value survey questionnaire by Robert Mitchell and Richard Carson. This concrete embodiment of the methodology has been extensively reviewed by the multidisciplinary project team and by the project advisers.

The EPRI methodology was administered on a pilot case basis in the eastern United States with the intent of examining how well it addresses the issues discussed earlier. Interviews were carried out with 150 respondents; materials such as photographs and "program cards" were used to illustrate the improvements that different emission control alternatives might achieve (Figure 1). A draft report discusses the methodology improvements realized by using the new survey design and identifies unresolved issues.

Preliminary results

Some important survey design clues have been elicited from this pilot program. For example, more than one-third of the respondents made errors in simple ranking tests on photographs (i.e., ranking photographs from best to worst visibility). This demonstrates the difficulty people have in distinguishing between small changes in visibility and indicates the important role of thresholds for visibility improvements. Below the thresholds, people are unable to appreciate the visibility change and may therefore assign it a low value.

Many respondents ranked alternatives strictly on either visibility or their monetary cost. A relatively high fraction (10% of the

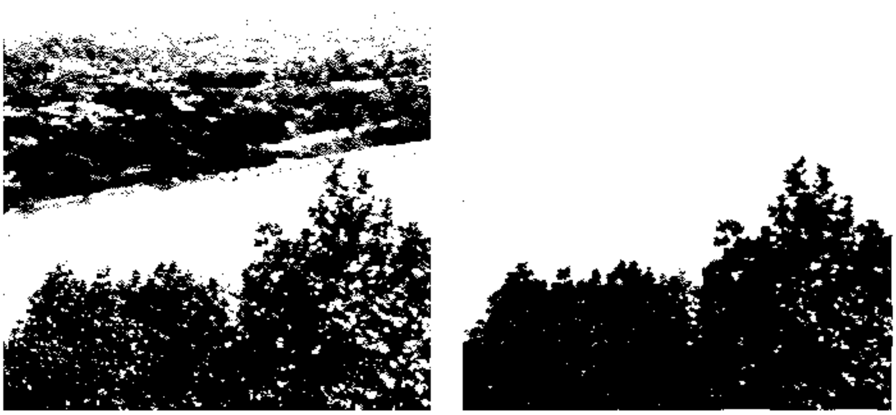


Figure 2 Using computer-modified photographs allows the CV researcher precise control over the levels of haze presented in an interview. Shown here are two different levels of haze that were added by computer to an original clear-sky photograph. These photographs have been tested in focus groups and found to be preferable to using actual photographs of alternative haze levels. Actual photographs are affected by slight changes in elements of the scene (e.g., leaf color and lighting) that are unrelated to changing haze levels.

sample) would pay nothing even for the greatest visibility improvement presented, and more than half of the sample would pay nothing for programs with fewer than six days of improved visibility. Conversely, 10% of the sample would pay more than four times the average for the whole sample. This indicates three distinct groups of people that should be treated differently in future analyses.

The results indicate a high level of uncertainty surrounding any interpretation of the quantitative conclusions of the research outcome. They also indicate that extrapolation from previous contingent valuation studies to new situations is problematic.

Future directions

EPRI's research has made a number of advances in applying contingent valuation to visibility values, and EPRI plans to continue these advances. Some of the next steps in the process incorporate computer-generated photographs into the survey instrument. Figure 2 illustrates the high quality of the computer-modified photographs that are now available.

The current work on eastern visibility valuation is scheduled to be completed by the end of 1990. Further into the research program, in 1991 and beyond, the methodology may be modified for use in national park areas.

Nuclear Plant Life Extension

LWR License Renewal

By Richard Burke, Nuclear Power Division

Recognizing the significant additional contribution that currently operating nuclear power plants could make toward satisfying our nation's electric power needs in the next century, the Department of Energy (DOE) and EPRI agreed in 1984 to conduct a cooperative program to extend the useful lives of nuclear power plants for a substantial period beyond the current, 40-year licensed operating lifetime.

Laying the groundwork

The first phase of the program involved pilot studies of a representative boiling water reactor (BWR), Monticello, and a representative pressurized water reactor (PWR), Surry Unit 1. Those studies, completed in 1988, resulted in the conclusion that there are no major technical or engineering-related obstacles that would preclude safe operation of either type of nuclear power plant appreciably beyond 40 years.

At present the operating licenses of more than half of the nation's 112 nuclear power plants are scheduled to expire within a period of 15 years, beginning in the year 2000. It follows, then, that a necessary next step toward realization of the goal established by EPRI and DOE is to clearly define and validate the regulatory processes that will govern the renewal of operating licenses for many of those plants.

The Nuclear Management and Resources Council (NUMARC), chartered to represent the industry in all matters involving generic regulatory policy issues and on the regulatory aspects of generic operational and technical issues affecting the nuclear power industry, formed its NUPLEX (nuclear utility plant life extension) working group in June 1988 to take lead responsibility for all industry activities related to license renewal. The primary goal of the working group is to have a predictable, workable, and demonstrated license renewal process in place by the early 1990s. EPRI and DOE are very supportive of that goal and have been closely coordinating their license renewal activities with those of the working group since its inception.

The collaborative efforts of the NUMARC NUPLEX working group, EPRI, and DOE have resulted in a number of documents bearing on license renewal, which have been submitted to the Nuclear Regulatory Commission (NRC) for review and comment.

Perhaps the most significant of these documents was submitted by the NUMARC NUPLEX working group in April 1989. Bearing the title *NUMARC NUPLEX Position Paper on License Renewal Rulemaking*, it sets forth the industry's proposal as to the contents of regulations the NRC should adopt to govern the renewal of nuclear power plant operating licenses. The proposed regulations are based on the premise that the NRC's review of a renewal application, in the absence of a rule waiver or a determination by the commission that further information is needed in an individual case, should be limited to identification and evaluation of systems, structures, and components that are significant to safety and subject to age-related degradation.

While the pilot plant studies initiated by EPRI and DOE in late 1984 did not reveal any major impediments to the operation of nuclear power plants in excess of 40 years, they did result in the identification of a number of areas that warranted further technical research. These additional studies are proceeding with EPRI and DOE funding under the guidance of the NUMARC NUPLEX working group. Two of the 10 subject investigations have recently been completed, and reports describing the results have been submitted to the NRC for review. These industry reports, as they are called, are entitled *PWR Containments* and *BWR Pressure Vessels*. At the time of this writing, the working group's schedule for the submittal of the eight remaining reports is as follows: *PWR Pressure Vessels* and *BWR Reactor Pressure Vessel Internals*, February 1990; *PWR Pressure Vessel Internals*, April 1990; *Cables in Containment*, *Class 1 Structures*, *PWR Reactor Coolant System*, and

ABSTRACT *The U.S. Nuclear Regulatory Commission is in the process of preparing a proposed rule for license renewal of currently operating commercial nuclear power plants. In order to provide timely exercise of the rule, a license renewal application must be submitted by a lead plant in the early 1990s. Applications will be prepared by two utilities, with active support from EPRI, DOE, and NUMARC. It is expected that these lead plant applications will establish the specific format and requirements for future submission and, by a feedback process, define or validate the confirmatory R&D needed to support license renewal.*

BWR Containments, June 1990; *BWR Primary Pressure Boundary*, August 1990.

Two additional products developed under the auspices of the NUMARC NUPLEX working group worth noting are its *Study of Generic Environmental Issues Related to License Renewal* and *Methodology to Evaluate Plant Equipment for License Renewal*. These were submitted to the NRC for review in May and October of 1989, respectively.

The generic environmental issues report presents an analysis of the environmental impacts expected to result from operating a nuclear power plant for 40 years beyond its initial license term. The study compares those impacts with the impacts of operation during the initial license term and the impacts of alternative sources of power. The analysis leads to the conclusion that the generic environmental impacts of operating a nuclear power plant during the license renewal period are lower than or comparable to the impacts resulting from operation during the initial license term. The analysis also shows that the generic environmental impacts of extended operation are lower than those estimated when the original plant operating licenses were granted.

As its title implies, the methodology document is intended to set forth the industry's thinking as to how nuclear power plant equipment should be evaluated in terms of its serviceability beyond the initial, 40-year license term. The methodology presented is based on the following precepts:

- License renewal focuses on ensuring continued safe operation for the license renewal period.
- License renewal is based on continuation of the plant's current licensing basis.
- Existing plant programs contribute to ensuring continued safe operation.
- Both deterministic and probabilistic approaches exist for identifying and reviewing equipment within the scope of review for license renewal, and for subsequently identifying plant equipment that requires further evaluation.
- A variety of options are available to address equipment that is identified for license renewal evaluation.

Refining the renewal process

Before nuclear power plant license renewal can be broadly viewed by the industry as a viable source of "new" electric generating capacity, a predictable and validated regulatory process must be in place. In January 1989, EPRI and DOE initiated a five-year research project specifically designed to facilitate attainment of that goal. As in the case of the earlier pilot plant studies, the $20-million-plus LWR lead plant license renewal project is being cofunded by DOE and EPRI, with substantial cost sharing by two contracted host utilities: Northern States Power and Yankee Atomic Electric. Project management services on behalf of DOE are being provided by Sandia National Laboratories.

The specific objectives of the project, being conducted at Northern States Power's Monticello BWR and at Yankee Atomic's Yankee plant, a PWR, are as follows:

- Successfully demonstrate the NUMARC NUPLEX working group's *Methodology to Evaluate Plant Equipment for License Renewal*.
- Perform plant-unique evaluations of systems, structures, and components identified through the methodology by utilizing the lessons learned from ongoing studies and incorporating the technology and methods provided in the EPRI reports on the pilot plant studies and the industry reports being developed under NUMARC NUPLEX working group guidance.
- Examine plant operational practices, maintenance programs, and data collection to support life extension.
- Prepare and submit a complete license renewal application to the NRC.
- Provide the basis—through appropriate technical, licensing, and codes and standards support—to maximize the applicant's probability of success in its interaction with, and response to inquiries from, the NRC, the EPA, FEMA, and other authorities, including local and state jurisdictions, during the license renewal process.
- Provide periodic feedback to the NUMARC NUPLEX working group on the progress of the lead plant license renewal project.
- Document the license renewal process for use by other utilities.

The planning phase of the LWR lead plant license renewal project has produced two principal products: detailed project management plans and the industry report on methodology.

Each of the participating utilities has prepared and published a project management plan outlining the project scope, resources, and schedule and indicating how these elements are to be coordinated and managed throughout the project, the level of corporate support that is to be provided, and the responsibilities and areas of authority of the project management team members. Each plan will be updated at approximately midyear each year during the course of the project.

As previously noted, the industry report *Methodology to Evaluate Plant Equipment for License Renewal* was developed under the auspices of the NUMARC NUPLEX working group and, in a strict sense, it is not a "deliverable" of the LWR lead plant license renewal project. The lead plants were responsible for its trial use, however, and for providing recommendations to the NUMARC NUPLEX working group as to how it could be improved to ensure consistent results. The report reflects the invaluable and rather extensive feedback provided by lead plant project personnel.

The second phase of the project, license renewal preparation, will culminate in the submittal of a license renewal application to the NRC by each of the lead plants. During this phase, all plant equipment evaluations will be completed and documented and the applications will be prepared. License renewal applications are scheduled to be submitted in June and December of 1991 by Yankee Atomic and Northern States Power, respectively. Intermediate reports describing the results of applying the NUMARC methodology to a representative portion of each of the lead plants were completed in December 1989. Reports describing the full application of the methodology at Yankee and Monticello will be available in April 1990 and January 1991, respectively.

The third and final phase of the project will be renewal licensing. After the license renewal applications are submitted to the NRC, there will be a period of technical reviews, meetings, and hearings that will very likely require the continuance of technical support to the lead plants. The project will be considered complete upon NRC disposition of the license renewal applications, which is currently expected to occur late in 1993.

Related tasks

A number of other products will be developed in connection with LWR lead plant license renewal project tasks. Each host utility will develop a report on the technical evaluations that will be required for the license renewal application. Whereas the reports on applying the *Methodology to Evaluate Plant Equipment for License Renewal* will focus on the identity of specific plant components whose suitability for continued use during the license renewal term warrants detailed evaluation, the technical evaluation reports will discuss those evaluations and the actions the utilities have determined to be appropriate in support of license renewal. The Yankee report will be available in January 1991, and the Monticello report, in July 1991.

Another key task at each of the lead plants will be the detailed examination of operating and maintenance practices to provide assurance that they are appropriate with respect to minimizing age-related concerns. Any improvements considered desirable to enhance license renewal at Yankee will be reported in January 1991, and any identified at Monticello will be reported one year later.

Plant life extension implementation plans based on the results of the detailed evaluation of components identified through application of the NUMARC methodology and the examination of O&M practices also will be developed by the lead plant utilities. The Yankee plan will be available in January 1991, and the Monticello plan, in January 1992. Yearly updates are scheduled. Most of the information being developed by the lead plants for ultimate use in support of their license renewal applications is being retained in electronic database format. Each host utility will publish a summary report describing the key information and data management techniques that were found to be most beneficial: Yankee, in January 1991, and Northern States Power, in May 1993.

Underground Residential Distribution

Increasing Distribution Cable Life

by William Shula, Electrical Systems Division

Polyethylene-insulated cable for 15-kV-class service was first used extensively in the 1960s to provide underground service to residences. A major factor leading to the quick acceptance of this new material was the trend toward underground residential distribution (URD) systems. Because polyethylene is inexpensive, is easily spliced and terminated, and has excellent dielectric properties, it was viewed as ideal insulation for URD cable. Thus, millions of feet of solid dielectric cable were placed in service without lengthy field trials or evaluations of performance life being conducted.

Within a few years, evidence mounted that polyethylene-insulated cable was not going to last the expected 40 years. High early-failure rates led to the examination of insulation removed from failing cables, which revealed a widespread form of degradation—treeing. Unlike conventional treeing, these failures developed only in the presence of water and thus were termed "water trees." In addition, URD cable was experiencing corrosion of the

ABSTRACT *High early-failure rates for polyethylene-insulated cable have spurred efforts to develop longer-lasting underground distribution cable. As a result of increased research, underground residential distribution cables put in service today are expected to outperform and outlast their predecessors. In designing cables for longer life, engineers are confronted with many choices concerning cable insulation types, construction methods, processing techniques, and installation procedures. The EPRI-developed* Distribution Cable Research Digest, *a compilation of industry research findings, has proved to be a valuable aid, as have EPRI computer codes and guidelines on cable pulling, neutral sizing, and insulation shield rating.*

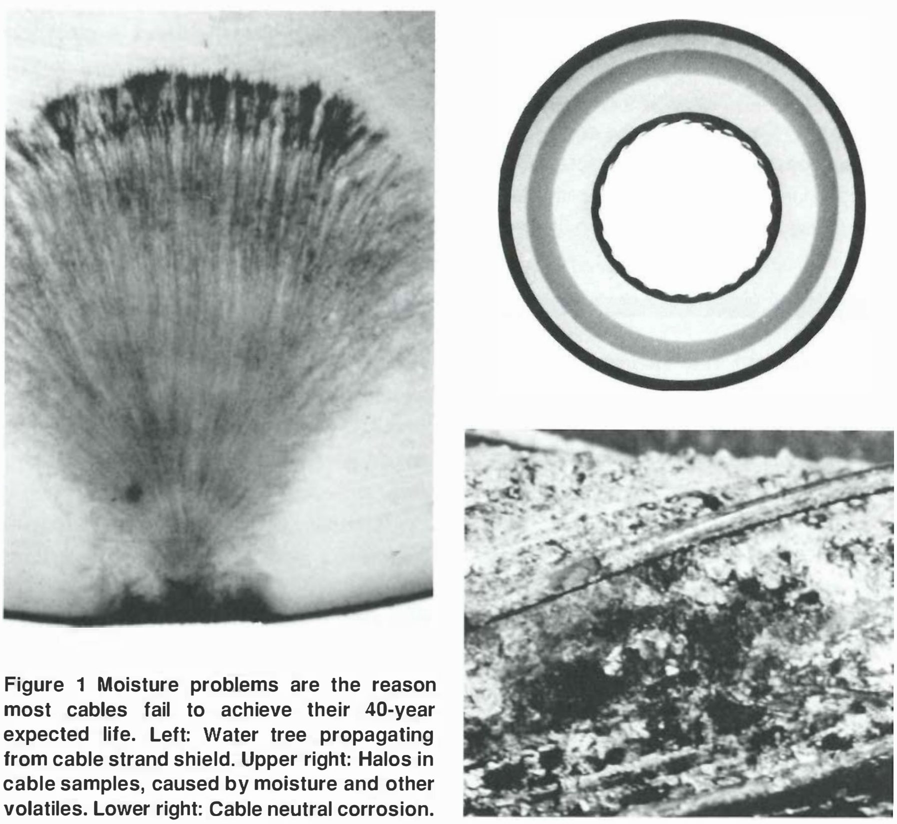


Figure 1 Moisture problems are the reason most cables fail to achieve their 40-year expected life. Left: Water tree propagating from cable strand shield. Upper right: Halos in cable samples, caused by moisture and other volatiles. Lower right: Cable neutral corrosion.

unprotected copper concentric neutral as a result of being directly buried without a protective covering (Figure 1).

Consequently, when EPRI began operations in 1973, cable insulation treeing and concentric neutral corrosion were among the first research topics addressed. The ultimate objective of work in this area has been to develop a superior, long-life distribution cable.

The cable specifications developed by the cable engineering section of the Association of Edison Illuminating Companies are used extensively by the utility industry. These specifications (AEIC-CS-5 for polyethylene and cross-linked polyethylene and AEIC-CS-6 for ethylene propylene rubber) are recognized as basic. The approach that EPRI has taken has been to supplement them with findings from recent research so that utilities can realize the benefits of increased cable life and cost-effectiveness.

Designing for long cable life

Today, the utility cable engineer is confronted with many choices concerning cable insulation, construction, and processing techniques. Cable insulations include tree-retardant high-molecular-weight polyethylene, cross-linked polyethylene (XLP), tree-retardant cross-linked polyethylene (XLPTR), and a variety of types of ethylene propylene rubber (EPR). Cable construction options include bare versus jacketed neutrals, solid versus stranded conductors, and unfilled versus filled strands. In addition, several jacket materials are available, and processing choices include steam and dry curing.

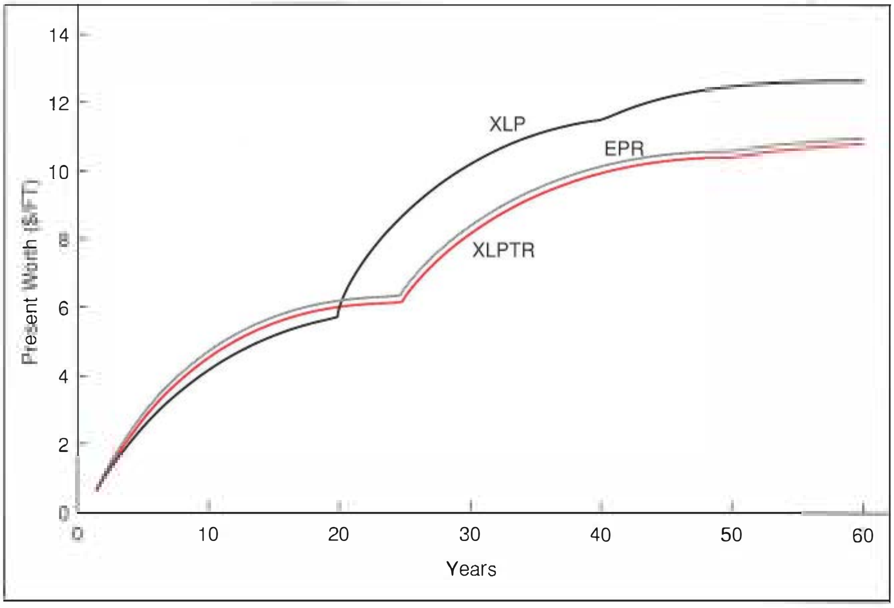
As a primary guide in selecting cable, EPRI suggests a comprehensive economic analysis based on the present worth of revenue requirements. This approach is necessary because a cable with a low first cost does not necessarily have the lowest lifetime cost. EPRI has developed an easy-to-use computer program for the economic comparison of alternative cable designs. The input parameters are easily obtained, and extensive technical skills are not required (Figure 2).

EPRI research has shown that cable life can be increased by exercising proper cable handling and installation practices and by supplementing AEIC specifications with criteria in such areas as insulation cleanliness, conductor and insulation shield materials, cable jacket materials, conductor concentricity, core conductor types, and cable processing methods and testing. While EPRI's criteria cover incremental changes that individually may seem minor, together the increments can add substantially to cable life. Going one step further, EPRI has developed suggestions concerning the best balance of cable cost, reliability, and service life. The materials and constructions considered are readily available and widely used for cable directly buried in earth or installed in conduit.

To help utilities develop specifications for improved distribution cable, EPRI has prepared the *Distribution Cable Research Digest* (EL-6271). This easy-to-use volume consolidates valuable cable information from various EPRI publications. It covers specifications for long-life cable, discusses economic considerations, and summarizes completed cable research projects.

A recent utility application illustrates the usefulness of this digest and of EPRI's cable economic analysis program. The utility analyzed various cable options to extend service life, including direct-buried cable with either XLP insulation, XLPTR insulation, or XLP insulation with an overall cable jacket. Using cable life estimates provided in the *Research Digest*, the utility performed an economic comparison of the options, incorporating investment costs, energy losses, and replacement costs. In this study, the XLPTR-insulated cable was found to be the most economical for each of four cable sizes (#2 aluminum, #2/0 aluminum, 500-kcmil aluminum, and 1000-kcmil aluminum). The study assumed that concentric neutral corrosion was not a problem. The utility points out, however, that a serious corrosion problem could make the jacketed cable an economically justified option.

Figure 2 Cable design economic analysis. This sample output of EPRI's economic analysis program for URD cable displays the present worth for three cables with a bare copper concentric neutral but different insulation types. The program also gives the levelized annual cost at 40 years (in $/ft-yr) for each option—$1.39 for the XLP-insulated cable, $1.20 for the EPR-insulated cable, and $1.18 for the XLPTR-insulated cable.



Cable-pulling code and guidelines

EPRI research has also focused on cable installation. In RP1519, EPRI set out to update maximum pulling lengths for a wide range of cable constructions. Laboratory tests were run on 23 types of solid dielectric cable (600 V through 138 kV) to determine the following:

- Static and dynamic coefficients of friction between various cable coverings and ducts, with and without pulling lubricants
- Maximum allowable pulling tension for copper and aluminum conductors pulled by eyes or grips
- Response of various cable constructions to shear loading
- Maximum allowable sidewall-bearing pressure for various cable constructions

The tests showed that these cables can tolerate tensions and sidewall-bearing pressures far in excess of the limits formerly considered acceptable. To assist utility engineers, EPRI developed a handbook containing pulling guidelines (EL-3333). It also developed the CABLPUL computer code (and an accompanying handbook) to help duct system design engineers quickly perform pull tension calculations. CABLPUL is available from the Electric Power Software Center individually or as part of the EPRI Distribution Workstation (DSWorkstation).

New Contracts

Customer Systems

Project	Funding/Duration	Contractor/EPRI Project Manager
Workshop on Residential Ventilation (RP2034-34)	$42,100 8 months	Energy International, Inc./ *J. Kesselring*
Attic Radiant Barrier Analysis (RP2034-36)	$23,300 5 months	Davis Energy Group, Inc./ *J. Kesselring*
Lighting-HVAC Interaction Study and Design Guidelines (RP2285-16)	$350,600 24 months	Ross & Baruzzini, Inc./ *K. Johnson*
Field Testing and Commercialization Support for Hybrid Breaker Remote Switch (RP2568-14)	$27,700 7 months	Plexus Research, Inc./ *L. Carmichael*
Cool-Storage Seminar Support (RP2732-31)	$38,400 6 months	Synergic Resources Corp./*R. Wendland*
Pinch Technology Case Study—Paper Plant (RP2783-19)	$115,600 8 months	Linhoff March Inc./ *K. Amarnath*
Development of Advanced Off-Peak or Base-Loaded Heat Pump Water Heaters (RP2958-9)	$80,400 5 months	E-Tech Division of Marvair Co./*C. Hiller*
Integrated Value-Based Planning: Understanding the Policymaker Perspective (RP2982-6)	$120,400 20 months	Temple Barker & Sloane, Inc./*P. Hanser*
Space-Conditioning System Characterization and Component Analysis and Selection (RP2983-13)	$75,700 4 months	Dorgan Associates, Inc./ *M. Blatt*
BIDMET Project (RP3086-1)	$69,900 7 months	Charles River Associates, Inc./*W. LeBlanc*
Overview of Commercial Electrotechnologies in Japan (RP3138-2)	$49,100 4 months	Energy International, Inc./ *M. Blatt*

Generation and Storage

Project	Funding/Duration	Contractor/EPRI Project Manager
Optimum Cycle Chemistry for Once-Through Units (RP1403-45)	$202,600 17 months	Black & Veatch Consulting Engineers/*R. Dooley*
Thin-Film Solid-Oxide Fuel Cell Electrolytes (RP1676-14)	$326,400 36 months	Northwestern University/ *R. Goldstein*
Improved Boiler Inspection Systems (RP1865-10)	$1,500,000 72 months	Babcock & Wilcox Co./ *S. Gehl*
Guidelines for FGD Materials and Corrosion Protection (RP1871-23)	$232,200 13 months	Battelle, Columbus Laboratories/*P. Radcliffe*
Early Applications of Photovoltaics in the Electric Utility Industry (RP1975-6)	$154,700 15 months	Ascension Technology/ *J. Bigger*
Geothermal Reservoir Assessment Based on Slim Hole Drilling (RP1994-4)	$400,000 17 months	University of Hawaii at Manoa/*E. Hughes*
EPRI Coal Quality Impact Model (RP2256-4)	$300,000 7 months	Black & Veatch Consulting Engineers/*A. Mehta*
CAES Thermodynamic Software Development (RP2488-16)	$39,400 8 months	Enter Software Inc./ *R. Schainker*
TVA Test Program Support (RP2543-12)	$243,800 12 months	Fluidized Bed Technologies Inc./*T. Boyd*
Power Plant Control Design for Utility Purposes (RP2710-12)	$267,000 27 months	Southern Company Services Inc./*S. Divakaruni*
Using Flue Gas Chromatography to Determine Coal Quality in Real Time (RP2819-13)	$43,000 6 months	Tennessee Technological University/*D. O'Connor*
Fossil Plant Simulation and Training Technical Support (RP2923-6)	$164,900 13 months	Science Applications International Corp./ *S. Divakaruni*
Permanent-Magnet Synchronous Motor (RP2984-1)	$491,200 20 months	Reliance Electric Co./ *J. Edmonds*
Quantifying the Dynamic Operation Benefits of Storage Technologies (RP3116-1)	$219,800 10 months	Electric Power Consulting Inc./*B. Louks*
HTSC Motor Development (RP3149-1)	$821,600 52 months	Reliance Electric Co./ *J. Edmonds*

Nuclear Power

Project	Funding/Duration	Contractor/EPRI Project Manager
Irradiation-Assisted Stress Corrosion Cracking Under Simulated BWR Conditions (RPC101-3)	$1,400,400 38 months	General Electric Co./ *R. Pathania*
Purchase of Results of Monticello's RPV Exam (RPC105-4)	$100,000 1 month	Northern States Power Co./*M. Behravesh*
Alloy 690 Qualification: Corrosion Tests Under Prototypic Heat Flux and Temperature Conditions (RPS408-6)	$611,900 31 months	Westinghouse Electric Corp./*A. McIlree*
BWR Stability Solution Method (RP958-5)	$120,000 14 months	Computer Simulation and Analysis Inc./*L. Agee*
Electrochemical Fusion Studies (RP2614-56)	$245,900 11 months	SRI International/*T. Passell*
Fundamental Experimental Study of Subcooled Bubbly Boiling Flow (RP2614-60)	$70,300 20 months	Arizona State University/ *S. Kalra*
Separate Effect Tests to Understand Cold Fusion Phenomena (RP2614-62)	$35,700 2 months	SRI International/*V. Chexal*
BWR Containments Industry Report (RP2643-30)	$124,100 9 months	Multiple Dynamics Corp./ *J. Byron*
Development of Three-Dimensional CAD Models of ALWR Conceptual Design (RP2660-54)	$48,700 4 months	Nuclear Information Sciences/*G. Vine*
Chemical Analysis of Advanced Containment Experiments—Phase C Samples (RP2802-17)	$50,000 8 months	AEA Technology/ *B. Sehgal*
Guideline for Maintenance of Terry Turbine Controls (RP2814-14)	$183,600 7 months	Dresser-Rand Co./ *R. Kannor*
Industry Consensus Terminology Related to Aging of Nuclear Power Plant Components (RP2927-7)	$75,300 15 months	MPR Associates/*G. Sliter*
Hydrogen Water Chemistry Fuel Surveillance at Hatch-2 (RP2946-4)	$855,300 62 months	General Electric Co./ *P. Rudling*
Development of Guidelines and Criteria for Nuclear Piping Evaluation and Design (RP2967-2)	$550,000 17 months	Duke Power Co./*Y. Tang*
Fracture Toughness Characterization of RPV Steels (RP2975-14)	$115,700 8 months	Materials Engineering Associates Inc./ *T. Griesbach*
Response Surface and Lookup Tables for Fire Vulnerability Evaluation Methodology (RP3000-39)	$70,000 10 months	University of California at Los Angeles/*J. Sursock*
Information-Gathering Guidelines for Fire Vulnerability Evaluation (RP3000-41)	$40,000 12 months	Professional Loss Control Inc./*J. Sursock*
Rapid Repair Adviser for Motor-Operated Valves (RP3007-1)	$100,000 7 months	Pacific Gas and Electric Co./*K. Sun*
Severe Accident Management Technology (RP3051-2)	$342,100 19 months	Fauske & Associates Inc./ *R. Oehlberg*
PWR Primary System Modeling Improvements for MAAP 3.0 B (RP3131-3)	$199,200 11 months	Science Applications International Corp./*F. Rahn*
Nuclear Power Data Collection Guide (RP3200-1)	$74,300 9 months	NUS Corp./*B. Chu*

New Technical Reports

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

CUSTOMER SYSTEMS

Status of Static UPS Applications in the United States
CU-6498 Final Report (RP2918-5); $100
Contractor: Chester & Schmidt Consultants
EPRI Project Manager: B. Banerjee

Office Productivity and Workstation Environment Control Workshop: Research Planning
CU-6556 Proceedings (RP2891-7); $100
Contractors: W. I. Whiddon & Associates, Inc.; Ostgren Associates, Inc.
EPRI Project Managers: M. Blatt, K. Johnson

Utility Opportunities for New Generation
CU-6605 Proceedings (RP2950-4); $100
Contractor: Synergic Resources Corp.
EPRI Project Managers: H. Gransell, W. LeBlanc

Requirements for an Advanced Utility Load Monitoring System
CU-6623 Final Report (RP2568-10); $25
Contractors: New England Power Service Co.; Plexus Research, Inc.
EPRI Project Manager: L. Carmichael

ELECTRICAL SYSTEMS

Far-Infrared Laser Inspection System for Cable
EL-6411 Final Report (RP794-4); $32.50
Contractor: United Technologies Research Center
EPRI Project Manager J. Porter

Probability Methods Applied to Electric Power Systems: Second International Symposium
EL-6555 Proceedings (RP1352); $70
EPRI Project Manager: R. Kennon

Substation Control and Protection Project: System Requirements Specifications
EL-6592 Final Report (RP1359-1); $32.50
Contractor: Westinghouse Electric Corp.
EPRI Project Managers: S. Nilsson, L. Mankoff

Substation Control and Protection Project: Communication Interface Specification
EL-6594 Special Report (RP1359-7); $25
Contractor: Westinghouse Electric Corp.
EPRI Project Managers: S. Nilsson, L. Mankoff

Extended Transient–Midterm Stability Program Package: Version 2.0, User Manuals
EL-6648 Final Report (RP1208-9); $32.50
Contractor: Ontario Hydro
EPRI Project Manager: M. Lauby

ENVIRONMENT

Precision of the EPA Seven-Day *Ceriodaphnia dubia* Survival and Reproduction Test: Intra- and Interlaboratory Study
EN-6469 Final Report (RP2368-2); $32.50
Contractor: Battelle, Columbus Division
EPRI Project Manager J. Mattice

MYGRT™ Code Version 2.0: An IBM Code for Simulating Migration of Organic and Inorganic Chemicals in Groundwater
EN-6531 Final Report (RP2879-2); $32.50
Contractor: Tetra Tech, Inc.
EPRI Project Manager: I. Murarka

Techniques to Develop Data for Hydrogeochemical Models
EN-6637 Final Report (RP2485-9); $47.50
Contractor: Radian Corp.
EPRI Project Manager: I. Murarka

Regional Integrated Lake-Watershed Acidification Study (RILWAS): Major Findings for Adirondack and Blue Ridge Mountains
EN-6641 Final Report (RP2174-1); $47.50
Contractor: Tetra Tech, Inc.
EPRI Project Manager: R. Goldstein

EXPLORATORY RESEARCH

1989 Symposium on Biological Processing of Coal and Coal-Derived Substances
ER-6572 Proceedings (RP8003); $350
EPRI Project Manager S. Yunker

GENERATION AND STORAGE

Dissimilar-Weld Failure Analysis and Development Program, Volume 8: Design and Procedure Guide for Improved Welds
CS-4252 Final Report (RP1874-1); $25
Contractor: The Materials Properties Council, Inc.
EPRI Project Manager: R. Viswanathan

Fabric Filters for the Electric Utility Industry, Volume 3: Guidelines for Fabrics and Bags
CS-5161 Final Report (RP1129-8); $32.50
Contractors: Southern Research Institute; Grubb Filtration Testing Services, Inc.; Electric Power Technologies, Inc.
EPRI Project Manager: W. Piulle

Fabric Filters for Electric Utility Industry, Volume 4
CS-5161 Final Report (RP1129-8); $750
Contractors: John P Clay, Consultant; Wm. Nesbit & Associates; Electric Power Technologies, Inc.
EPRI Project Manager: W. Piulle

Remaining-Life Estimation of Boiler Pressure Parts, Volume 3: Base Metal Model
CS-5588 Final Report (RP2253-1); $32.50
Contractors: Combustion Engineering, Inc.; Central Electricity Generating Board
EPRI Project Manager: R. Viswanathan

Remaining-Life Estimation of Boiler Pressure Parts, Volume 4: Metallographic Models for Weld-Heat-Affected Zone
CS-5588 Final Report (RP2253-1); $40
Contractors: Combustion Engineering, Inc.; Central Electricity Generating Board
EPRI Project Manager: R. Viswanathan

Guidelines for the Prevention of Economizer Inlet Header Cracking in Fossil Boilers
GS-5949 Final Report (RP1890-6); $10,000
Contractor: Ontario Hydro
EPRI Project Manager: D. Broske

NUCLEAR POWER

Chemical Decontamination of BWR Fuel and Core Materials: Hot Cell Examination of BWR Fuel
NP-6515-M Final Report (RP2296-12; RP2460-1); $25
Contractor: Babcock and Wilcox
EPRI Project Managers: H. Ocken, R. Yang

Integral Transport Computation of Gamma Detector Response With the CPM2 Code
NP-6527 Final Report (RP2352-3); $32.50
Contractor: S. Levy Inc.
EPRI Project Managers: R. Breen, O. Ozer

Deposition of Cobalt on Surface-Treated Stainless Steel Under PWR Conditions
NP-6528 Interim Report (RP2008-1); $25
Contractor: Atomic Energy of Canada, Ltd.
EPRI Project Manager: H. Ocken

BWR Pilot Plant Life Extension Study at the Monticello Plant: Phase 2
NP-6541-M Final Report (RP2643-2); $32.50
Contractor: Northern States Power Co.
EPRI Project Manager: M. Lapides

Evaluation of Fire-Retardant Fluids for Turbine Bearing Lubricants
NP-6542 Final Report (RP2969-2); $32.50
Contractor: Encotech Inc.
EPRI Project Manager: J. P Sursock

Fuel Consolidation Demonstration: Spent-Fuel Storage Area Analysis
NP-6551 Interim Report (RP2240-2); $120
Contractor: Northeast Utilities Service Co.
EPRI Project Manager: R. Lambert

CALENDAR

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

APRIL

2–6
Analysis and Design of Transmission Structures
Haslet, Texas
Contact: Dick Kennon, (415) 855-2311

10–11
Competitive Power Markets: Implications for Utility Operations and Strategic Positioning
Baltimore, Maryland
Contact: Steve Chapel, (415) 855-2608

10–11
Monitoring Equipment Environments During Nuclear Plant Operation
Baltimore, Maryland
Contact: George Sliter, (415) 855-2081

10–12
Electric Thermal Storage Users Group Meeting and Exposition
Washington, D.C.
Contact: John Kesselring, (415) 855-2902

17–19
Conference: Life Assessment and Repair Technology for Combustion Turbine Hot-Section Components
Phoenix, Arizona
Contact: Vis Viswanathan, (415) 855-2450, or James Allen, (415) 855-8929

17–20
Transmission Tower Foundations
Haslet, Texas
Contact: Dick Kennon, (415) 855-2311

23–25
New Technologies: Issues in Occupational and Environmental Health
Bethesda, Maryland
Contact: Cary Young, (408) 755-4301

24–27
Electrical Potpourri
Haslet, Texas
Contact: Dick Kennon, (415) 855-2311

MAY

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

2–4
Innovative Pricing and Planning
Milwaukee, Wisconsin
Contact: Bill LeBlanc, (415) 855-2887

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

25–29
Control Center Operator (Dispatcher) Training Simulator
Philadelphia, Pennsylvania
Contact: David Curtice, (415) 855-2832

JULY

29–August 3
International Conference: Indoor Air Quality and Climate
Toronto, Canada
Contact: Cary Young, (408) 755-4301

AUGUST

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

SEPTEMBER

18–20
Conference: Condenser Technology
Boston, Massachusetts
Contact: John Tsou, (415) 855-2220

OCTOBER

15–17
Incipient Failure Detection: Predictive Maintenance for the 1990s
Philadelphia, Pennsylvania
Contact: John Scheibel, (415) 855-2850

NOVEMBER

14–16
1990 Market Research Symposium
Atlanta, Georgia
Contact: Thom Henneberger, (415) 855-2885

Authors and Articles


Geraghty


Barker


Armor

Consortia for R&D Advantage (page 4) was written by John Douglas, science writer, with guidance from **Dom Geraghty**, director of EPRI's corporate and strategic planning.

Geraghty was named to his present position late in 1989 after serving as executive assistant to Richard Balzhiser, EPRI's president, for nearly three years. He was previously a technical manager in the Institute's Utility Planning Methods Center, where he developed information on plant investment options, including analytical techniques and software to aid decision making. He joined EPRI in 1977 after spending four years as an engineer and energy analyst with Irish government agencies. Geraghty has a BE and a PhD in chemical engineering from University College in Dublin and an MBA from the University of Santa Clara. ■

Making Connections: The Power of Information Technology (page 16) draws together threads of fact and insight about electronic information technology and its implications for utilities. **Brent Barker**, EPRI's manager of corporate information, wrote the article from what was said at the 1989 annual seminar of EPRI's Advisory Council, held last August.

Barker served as the *Journal*'s editor in chief for 12 years, until last fall. He came to EPRI in 1977 after working successively as a research analyst at USX Corp., an industrial economist at SRI International, and a communications consultant. Barker graduated in engineering science from Johns Hopkins and earned an MBA at the University of Pittsburgh. ■

The Soviet Power Industry Opens Its Doors (page 28) was written by Jon Cohen, science writer, assisted by **Tony Armor** of EPRI's Generation and Storage Division.

Armor has headed the Fossil Plant Performance Program since its formation in 1985. He came to EPRI six years earlier as a project manager. From 1968 to 1979 he was with General Electric, first as a technical leader in steam turbine engineering and then as a program manager for superconducting generator design. Before that he taught in polytechnic schools in London, England. Armor has a BS in mathematics and an MS in mining engineering from the University of Nottingham. ■

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