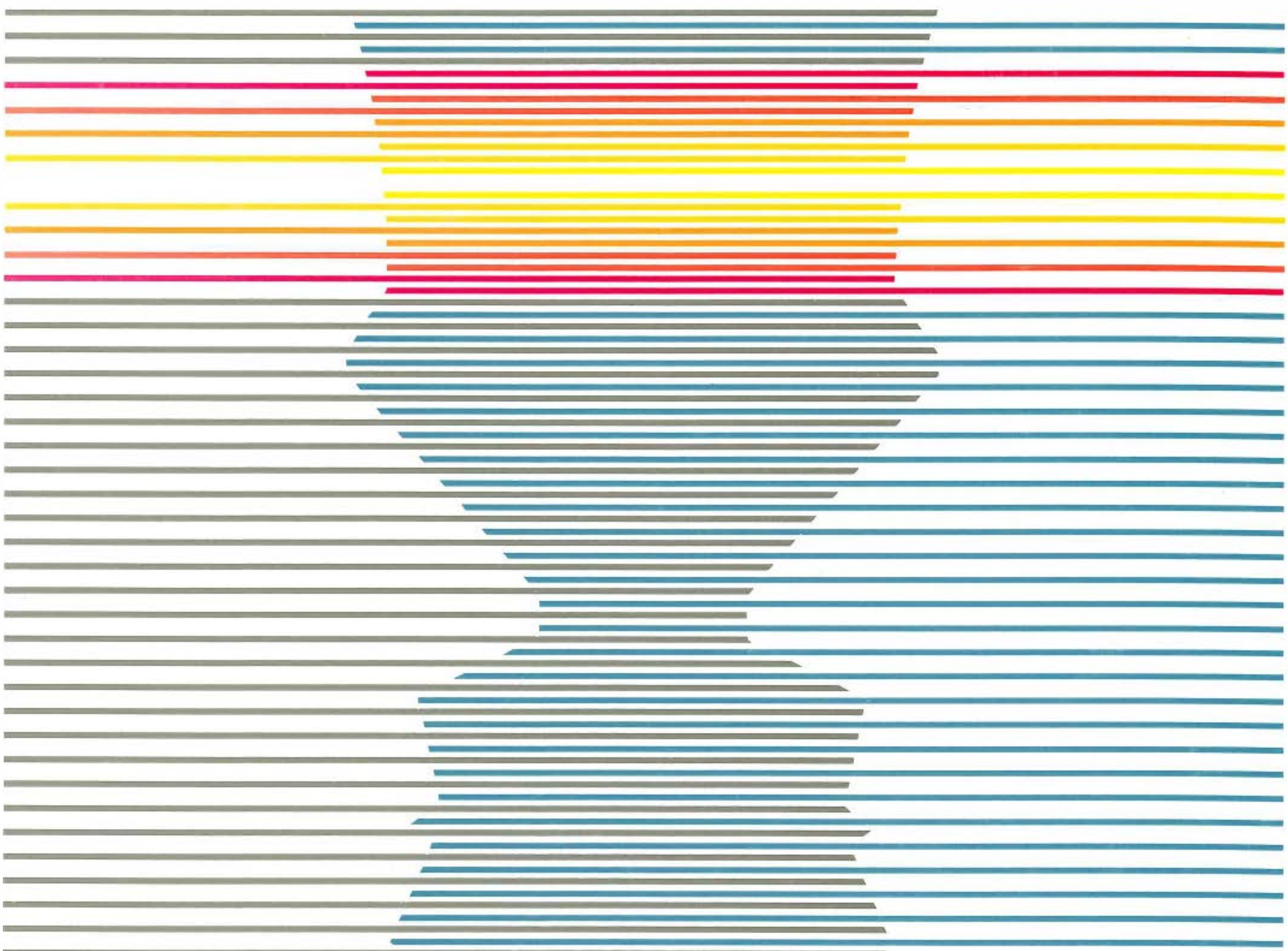
Transferring Technology

ELECTRIC POWER RESEARCH INSTITUTE

EPRI JOURNAL

NOVEMBER
1981



EPRI JOURNAL is published monthly, with the exception of combined issues in January/February and July/August, by the Electric Power Research Institute.

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

Address correspondence to:
Editor
EPRI JOURNAL
Electric Power Research Institute
P.O. Box 10412
Palo Alto, California 94303

Cover: To deal with the enigmatic problem of technology transfer, one must see it in its most basic terms—as a matter of communication between individuals.

EPRI JOURNAL

Volume 6, Number 9 November 1981

Making the Transfer Work

Technology transfer is a very popular concept these days. Universities study it; corporate departments are created to foster it; consultants offer services to promote it. And during the past several years, technology transfer has become an increasingly important topic for EPRI management. This month's lead article describes some of the approaches currently being explored to ensure that the ever-increasing number of results from EPRI's research programs are quickly and broadly applied to benefit the electric utility industry and its customers. I stress *currently* because, within EPRI, technology transfer is a dynamic, constantly changing process.

The article does not prescribe a set of rigid procedures that spell out with precision how one goes about transferring a new product (hardware, software, or information) from the laboratory to the user. It would be convenient if such a formula existed, but it doesn't. At EPRI, research is oriented toward its applications from the beginning: the needs of the electric utility industry are clearly identified by the industry advisory committees, the research programs are developed with the active involvement of the member utilities, and the vendors that will be responsible for providing the services or products are active participants in the research effort. But even with these advantages, technology transfer from EPRI to the utility industry is very complex. This complexity is the result of the many different types of research products involved, the diversity of EPRI's member utilities, and the challenge of providing the information to the right person within a given utility.

There are literally hundreds of products being developed by EPRI, ranging from small circuit breakers to large power generation systems and from environmental data bases to computer programs for three-dimensional stress analysis. In designing ways to accelerate the use of these products, each category of results must be handled according to its unique characteristics. The next consideration is the wide range of needs and capabilities that exists within the utility industry. EPRI members range from small distribution utilities with limited in-house technical capability to large generating systems that do all their own architect-engineering work. Information on research results must be prepared in such a way that it is useful across this entire spectrum. The final challenge concerns the difficulty of getting information on important research results from EPRI into the hands of the specific utility engineers who need it. The communications network within each electric utility is typically complex, dynamic, and unique. It is, therefore, important that EPRI understands and is sensitive to personnel communication routes within its member utilities.

The key to successful technology transfer lies not in procedures but in people. For EPRI's transfer efforts to succeed, all the participants must be aware of their responsibilities and actively involved in the process. EPRI project managers must be aware that their responsibility for a given project does not end with the publishing of a final report but continues until the product is successfully applied on a utility system and is commercially available. EPRI management must be willing to try innovative ways of ensuring that information on R&D results is understandable, application-oriented, and available to the people who need it. And the management of each utility must ensure that an appropriate system exists for getting the research results to the part of the organization that can use them; utility management must also make it clear that the utility is committed to promoting the widespread and early use of new research results on its system.

Richard L. Rudman

Richard L. Rudman
Director
Information Services Group

Authors and Articles

Technology transfer sounds straightforward enough—almost too much so: as if an item is delivered and signed for and that's the end of it. In fact, the phrase refers to a great variety of tasks and communications between research and the everyday use of its results.

Technology Transfer: The Ultimate Measure of R&D (page 6) explains how EPRI is identifying and organizing those tasks and communications so the paths are clearer and shorter. The author, science writer John Douglas, draws his examples from many EPRI activities, most of them in the newly formed Information Services Group, directed by Richard L. Rudman.

Rudman, once associated with IBM as a consultant on engineering computing, came to EPRI in March 1973 as assistant to the president. He organized an R&D planning staff a year later, and for the last two years he headed the Policy Planning Division. Rudman's new responsibilities encompass the Institute's communications, technical information, and member services. Rudman graduated from the University of California at Los Angeles and also earned an MS in nuclear engineering there.

■

Need for a computer software system that can simplify the manipulation of complicated nuclear engineering data bases has been growing. Richard Karlgaard describes such a system in **DATATRAN for Easy Access** (page 14), which he prepared from material provided by several sources.

Robert Whitesel, now with General Public Utilities Corp., was a project manager for the Code Development and Validation Program of EPRI's Nuclear Power Division. Whitesel, along with John Lamont, a project manager for the Power Systems Planning and Operations Program in the Electrical Systems Division, wrote a technical paper in 1980 on DATATRAN.

G. A. Mortensen, G. A. Cordes, and R. K. House, staff members of Intermountain Technologies, Inc., wrote another paper on the DATATRAN system's use for the widespread communication and manipulation of engineering data among utilities, manufacturers, and researchers. To round out the picture, Karlgaard also interviewed Harold J. Kopp of Technology Development of California, who worked on the development of DATATRAN when he was at Knolls Atomic Power Laboratory.

■

Ignorance in the mid-1960s and alarm in 1975 have been replaced in 1981 by knowledgeable confidence about the causes and cures of cracks that have shown up in some piping of boiling water reactors. **BWR Crack Control** (page 18), by science writer Richard Immel, explains the special circumstances that produce intergranular stress corrosion cracking (IGSCC), the mechanisms involved, and the variety of metallurgic, fabrication, assembly, and field remedies that are now flowing from concerted industry R&D efforts.

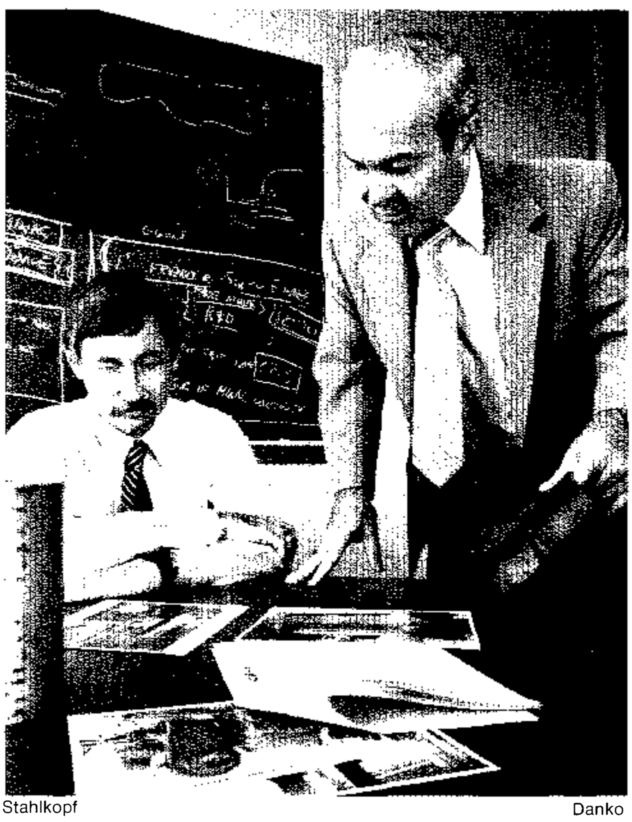
Two leaders of those efforts are Karl Stahlkopf, director of the Systems and Materials Department in EPRI's Nuclear Power Division, and Joseph Danko, manager of EPRI's program in IGSCC, predominantly funded by electric utilities of the BWR Owners Group. Stahlkopf has specialized in material and process phenomena at the pressure boundary of nuclear power systems since he joined the Institute in November 1973. He was previously a research fellow at the University of California at Berkeley while earning an MS and a PhD in nuclear engineering. Stahlkopf was a naval officer for seven years, involved in the construction and operation of submarine propulsion systems.

Danko came to EPRI in October 1978, having been in the nuclear technology department of General Electric Co. for seven years as manager of material and process development. His work there included methods to detect and prevent stress corrosion cracking. Between 1956 and 1971, Danko worked in thermionic and other advanced power developments for Westinghouse Electric Corp. and General Electric. A graduate of Carnegie-

Mellon University in metallurgical engineering, he earned an MS and a PhD in the same field at Lehigh University.

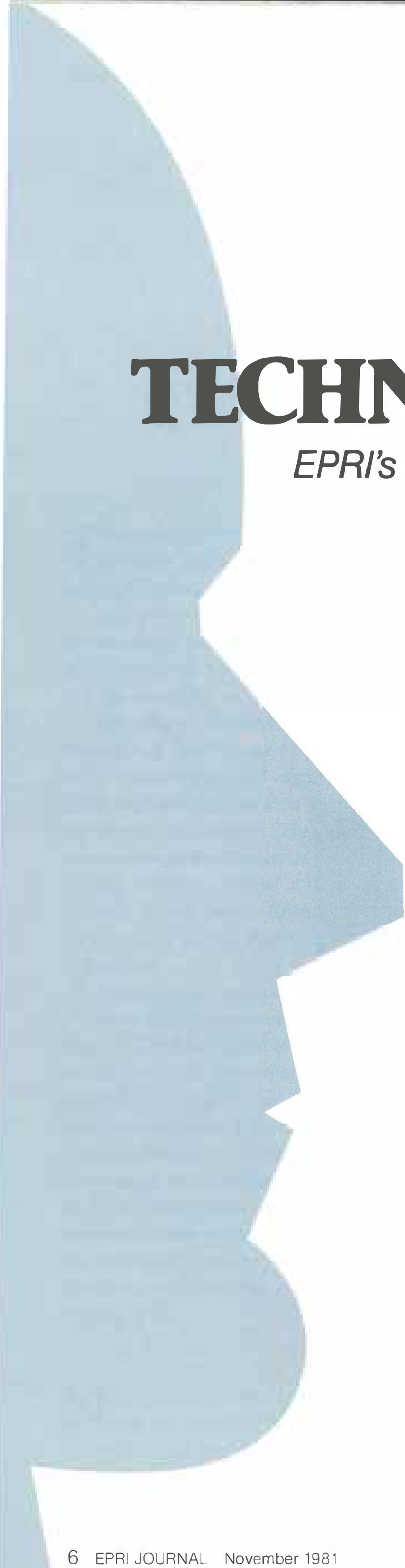
■

Watchwords from the man who chairs EPRI's Advisory Council are offered in the profile **Robert Sproull: Seeking the R&D Target** (page 24). Sproull has taught physics, planned and conducted research, obtained funding for R&D, managed a research laboratory, directed a federal R&D agency, and now combines nearly all those practices in the administration of a university. Ralph Whitaker, feature editor of the *Journal*, wrote this article after an interview with Sproull at the University of Rochester.



Stahlkopf Danko

Rudman



TECHNOLOGY TRANSFER

EPRI's challenge is to find R&D solutions to the technical pr
But in the final analysis, that challenge ha

A steady stream of useful products and processes are now being produced by EPRI's R&D program. The variety is great, ranging from new commercial products to technical handbooks, and such results represent a savings to utilities of hundreds of millions of dollars. However, the task of transferring this technology from EPRI to the specific utility personnel who can put it into practice has always been difficult. As EPRI's research programs have matured, the quantity of information involved has grown rapidly, and more resources must be devoted to move these practical systems to where they are needed in utility systems. In recognition of this need, EPRI management is now working with utilities to find new avenues for technology transfer. The immediate goal is to make each member utility aware of what is available.

"What we are trying to do," says R. L. Rudman, director of EPRI's Information Services Group, "is to use the increased

The Ultimate Measure of R&D

lems being faced by the utility industry and its customers.
ot been met until the technology is on-line.

flow of research results as an opportunity to explore alternative methods of technology transfer and to assess their effectiveness."

Passing highly technical information from a research setting to individuals in many disciplines scattered through many utilities, architectural and engineering firms, and vendor companies is very complex indeed. The task can perhaps best be understood through an illustration. Suppose the manager of a utility substation is getting complaints from the local town council about transformer noise. If the matter is serious enough, he initiates a request for a solution that begins working its way through the company's various communications channels.

Meanwhile, someone in the utility should have received at least two technical reports and other supporting material from EPRI about a new and inexpensive method to control transformer noise by acoustically tuned enclosure panels. So the key question of technology trans-

Bonneville Power Administration's improved fumigant treatment controls biological deterioration of wood poles and thus avoids their premature retirement.

fer is this: Is there some mechanism within the company that can link a technical problem with its solution in time to avoid much more expensive alternatives? Bonneville Power Administration took advantage of just such a connection in 1980 and eliminated a capital investment of $4.3 million by installing tuned panels at its McLoughlin station.

The process of technology transfer involves several steps. Information from a research project must be prepared for transmittal from EPRI; appropriate audiences must be identified; and once the information has been received by a utility, it has to be routed to the individuals who can act on it most quickly. Unused research results represent an unaffordable expense, but making this final internal connection can also be costly—utility officials report having to spend increasing amounts of time on handling the internal flow of technical information.

The size of the task was revealed in the results of a recent survey conducted at a major utility. A list of EPRI results was presented for evaluation on applicability, and utility personnel were asked which of the research results they were aware of. Although more than half of the items were judged "presently applicable" to the utility's operations, the individuals surveyed had been aware of only about half of those results judged applicable.

Meeting the challenge

This situation is far from unique. Bottlenecks to technology transfer occur in every industry that depends on a steady stream of R&D results. Lack of support from manufacturers may delay introduction of a technology. Failure to foresee the need for supplementary technology may cause rejection of a basically sound idea. And failure by research-oriented personnel to effectively communicate with the ultimate decision makers can hinder adoption of a technology.

Such problems must be expected—technology transfer is a practical matter and thus carries with it powerful real-world limitations. The biggest hurdle is the quantity of information. In the illustration given above, it would obviously be impractical for the manager of the substation with the noisy transformer to receive all EPRI reports. Nor could EPRI's technical staff be expected to anticipate all the utility personnel that might profit from receiving a particular report. Improved technology transfer must therefore involve establishing adequate procedures within the recipient companies for channeling information to those who can use it.

A related concern is complexity. No one can be an expert in all the technical fields related to his industry. Many individuals, representing a wide range of needs and abilities, are involved in technology transfer. The originator of technical information must therefore provide a variety of communication channels and present the information at different levels of complexity to suit multiple audiences, including some outside the industry primarily concerned.

There is a need for feedback. Direct personal links must be established between the scientists and engineers at a research institution and the users of their research results. This would allow the information recipients to ask questions and provide EPRI's technical staff with an opportunity to gain operational field experience and thus fine-tune a technology to meet a utility's specific needs. Such contacts can range from quick phone calls to formal workshops or extensive joint projects.

To meet these challenges, EPRI and its member utilities have already devoted considerable effort to technology transfer. Each utility can nominate representatives to serve on the industry task forces and advisory committees that work closely with the Institute's technical staff. Each utility also appoints its own technical information coordinator, who is responsible for making EPRI reports available to other utility personnel.

For its part, EPRI provides a variety of media to supplement technical reports. These include the *EPRI Journal,* which has a circulation of 30,000; the *Executive Report,* which provides top utility management with summaries of research results; and *Video Memos,* which are 15-minute videotape presentations on various aspects of EPRI R&D. Research results that utilities could apply in the near term are reported annually in EPRI's *Research Results and Applications.* One-page "Technical Application" sheets address specific problems facing utilities, review the research initiated to find a solution to a problem, and report how the product of that research is being applied in utility systems. Each of these vehicles represents a communications shortcut compared with the laborious task of reading detailed technical reports. Their aim is to consolidate information and make it more accessible to a broad audience.

Additional opportunities for technology transfer through direct contact are provided by various personal networks. EPRI's member services representatives, for example, work directly with utility personnel to help them make use of the Institute's resources. All have technical training and act as EPRI's ombudsmen, as well as provide the Institute with feedback from their network of utility contacts. The three utility industry trade associations also have several special-interest networks, such as the EEI Engineering and Operations Committee, that monitor EPRI work of specific interest to their areas and report their findings through established liaison systems. And utilities interested in the development and early application of a particular technology—fuel cells, for example—have begun establishing users groups, with EPRI support.

R&D payoff

These technology transfer mechanisms have already helped electric utilities throughout the United States apply the results of EPRI research, and such applications represent an immediate payoff on the industry's R&D investment. A few examples can illustrate just how valuable this technology transfer has been to some individual utilities.

One of the messages EPRI constantly receives from the industry is that the life of present equipment needs to be extended. One research response has been the development of several devices that detect incipient failures in turbines and generators before they cause major breakdowns. The savings that can be realized from using such devices became clear when prototype monitors detected abnormal arcing in two generators at the Martin Lake station of Texas Utilities Generating Co. in 1979. The company estimates it saved $500,000 that year alone in repair costs, and the monitors may have prevented single-event arc-related failures that would have cost as much as $18 million.

When equipment must be replaced, other near-term EPRI research has provided utilities more efficient or less costly equipment to upgrade their systems. In some cases, fundamentally new technology has been developed. One important example is the new two-phase transformer that will soon begin to replace PCB-insulated units in confined spaces where fire protection is at a premium. The manufacture of nonflammable PCB liquids is now forbidden, and oil-filled transformers sometimes require extraordinary precautions for fire prevention. The new system uses a fluorocarbon liquid that vaporizes inside the transformer. Consolidated Edison Co. has installed and successfully operated a scaled-up, 6000-kVA version of the transformer at its Ravenswood generating station.

Improved procedures and handbooks can also be extremely useful. For example, as rights-of-way for transmission lines become more difficult to obtain, many companies are looking for ways to send more power over existing corridors. EPRI has published the *Transmission Line Reference Book, 115–138-kV Compact Line Design* to show how the voltage in cir-

Coal blending with the aid of a continuous nuclear assay system is being used at Detroit Edison Co.'s 3000-MW Monroe station to economically meet sulfur dioxide emission standards.

Georgia Power Co. has prolonged the useful life of transmission line conductors by coupling in-service inspection with dampers on lines subject to aeolian vibration.

cuits can be doubled without the need to expand a right-of-way. By using this book as a guide to upgrade an existing 69-kV line to 138 kV, Utah Power & Light Co. realized a savings of about $4500 per mile.

A very different sort of technology transfer is involved when utilities need information to correct generic design deficiencies or to evaluate alternative designs of a proposed piece of equipment. Boiler feedpumps, for example, have been one of the major causes of forced outages in large fossil fuel power plants. To help utilities select the most reliable pumps for their particular circumstances, EPRI studied the operating history of over a thousand feedpumps to determine the leading causes of failure. The information, passed to utilities, indicated that reliability may vary more than 50% among the various designs available. In the case of one utility, Tampa Electric Co., this knowledge enabled engineers to select a feedpump design expected to save approximately 35 hours of plant downtime per year.

Demonstration of a technology on the facilities of a member utility provide a rich opportunity for direct transfer of technology. To avoid building expensive flue gas scrubbers to meet sulfur dioxide emission standards mandated by the Environmental Protection Agency, many utilities are trying to blend various grades of coal. Until recently, however, equipment was not available to optimize the use of expensive low-sulfur coal in a blend. EPRI's solution was to develop a system for the continuous on-line nuclear analysis of coal (CONAC). A prototype sulfur meter, a CONAC device, monitors the sulfur content of coals by bombarding them with neutrons and analyzing the returning radiation spectrum. Detroit Edison Co. estimates that by installing a CONAC system at its 3000-MW Monroe station, it realizes an annual savings of $13 million, compared with alternative methods for sulfur dioxide control.

A hotel conference room at the Dallas, Texas, airport was the setting last summer for an important inquiry into technology transfer. In a two-day workshop, six of EPRI's member utilities explained their practices and shared ideas for the transfer process.

This was no evaluation of low-NO_x burners, solid-state surge arresters, or induction heating methods. Instead, it was a review of how a few utilities handle the traffic of R&D information flowing from EPRI (and elsewhere) so that the technology content itself is sure to be seen and evaluated for application.

The workshop participants were Bobby Barnes of Carolina Power & Light Co.; Ashby Baum of Virginia Electric and Power Co.; Joseph Credit of Colorado Ute Electric Association, Inc.; Edward Gastineau of Central and South West Corp.; David Jopling of Florida Power & Light Co.; and Joseph Legate of Nashville Electric Service. These men share a single characteristic: each is his organization's official or functional coordinator of EPRI information in whatever form it is made available—reports, summaries, films, workshops, data sheets, newsletters, computer programs, seminars, data bases, and even this magazine.

Otherwise, the coordinators are strikingly different in their backgrounds and in their company roles. Credit, for example, has been a utility engineer for 33 years (28 of them in New England). Now in charge of engineering and construction for Colorado Ute, he is one of three vice presidents who guide the rural cooperative utility's immediate operations. Credit's recommendations on R&D matters can get chief executive attention over a weekend—in hours, when necessary.

Barnes, in contrast, was a civil engineering professor at North Carolina

State University only two years ago. Now, as CP&L's liaison to EPRI, he is one of three professionals working closely with an in-house R&D steering committee that guides seven specialized working groups. These groups identify research needs, monitor developments in their areas of interest, and act as conduits for passing EPRI research results back to the operating level.

Like the coordinators themselves, the utilities represented at the workshop share one characteristic: they are among the most actively inquisitive EPRI members. It would therefore have been easy to conclude that the ideas shared at the workshop would be most beneficial to the less-active utilities. There was easy assent to the analogy of a preacher who disarmingly insists, "Now, my message today is really for the folks who aren't here."

EPRI's approximately 630 members represent more than 70% of annual U.S. electricity generation. And between 700 and 800 utility professionals serve on EPRI's many advisory committees, task forces, program committees, working groups, and project review teams. Still, as Rudman observed, more than 450 members have named no one to coordinate the EPRI research summaries now being mailed at a two-a-day clip—about 750 a year.

A conclusion thus becomes apparent—the technology transfer process, like other effective communication, requires constant effort to get and hold attention, as well as to transmit information. What this means is that commitment from utility management is essential, both as an example to others and as an instrument of active guidance.

There was discussion of how EPRI might aid utility managements in this phase. One approach would be to frame guidelines for R&D coordination in utilities of different sizes—outlining the skills, organization, budget, time, authority, responsibility, and procedures that have been found useful. Also, by studying the market potential of new technologies as part of their projects, EPRI research managers can build in the steps needed to carry R&D results to a larger utility audience. Thomas Crawford, director of the Institute's Technical Information Division, suggested that EPRI's mailing lists to utilities might be expanded and more precisely coded to put the right material in the right hands at the right level, that is, where the technology decisions are made.

The consensus here, as in other parts of the two-day Dallas meeting, was that the variety of utility sizes, ownership circumstances, service conditions, technology needs, organization forms, and management styles preclude most steps EPRI could take toward more specialized or insistent initiatives. At different times, Florida Power & Light's Jopling and Central and South West's Gastineau pointed out that leading a horse to water does not make him drink. Vepco's Ashby Baum was specific about a utility's role. "We have an obligation to participate in the R&D that is likely to touch us—to express our interests and needs, to take advisory roles, and to review the work as it goes on."

Baum was equally emphatic when he added, "When projects are done and the reports come to our doorstep, it's up to us to distribute them to the right people and to decide whether and how Vepco can benefit from the R&D findings. EPRI shouldn't have to force the results on us. We're the ones to do our own recommending." The remark does much to distinguish EPRI's role from that of a consultant. EPRI is a member-supported clearinghouse of technology options and the information to support them. A consultant has a more direct responsibility to recommend specific courses of action to a client.

The specialized R&D communication that everyone acknowledged to be effective is the good old standby, one-to-one conversation. Carolina Power & Light's Barnes said he simply telephones someone he knows at EPRI, describes his problem, and asks for the staff member who works in the subject area. Barnes's approach is now possible for anyone who calls a new hot line into EPRI: (415) 855-2411. This number is more than a directory service. For cases satisfied by references to published sources, it eases what could otherwise quickly become an intolerable volume of telephone traffic for the Institute's technical staff.

Jopling and Florida Power & Light carry the process of direct contact still further by encouraging that utility's professionals to be active in the many EPRI advisory groups. In this way, they are privy to the R&D that interests them, they can be sure that their questions are answered in the course of the research, and they develop a familiarity that makes eventual application of the R&D much smoother for Florida Power & Light.

Differences in utilities, especially in their communication networks and decision channels, are the key factors that EPRI and its members must accommodate in the technology transfer process. R&D information must be varied in level, length, format, and medium so as to be useful to members with different needs. EPRI can push the availability of technology widely, but utilities ultimately must pull the transfer media and technology options they themselves select. □

Prototype radio frequency monitors installed on two generators of Texas Utilities Generating Co.'s Martin Lake station have detected abnormal arcing early enough to prevent major damage.

Field-testing new technology

Technology transfer through the use of EPRI-sponsored test facilities is another important aspect of EPRI's program. This can best be illustrated by progress being made at two major new evaluation and test facilities. The Nondestructive Evaluation (NDE) Center, dedicated in Charlotte, North Carolina, earlier this year, provides the industry with a testing ground to ensure that NDE procedures and equipment developed through EPRI's research program are field-qualified. In addition, the center provides training to utility personnel and their service contractors in the skills necessary for the application of NDE techniques.

Construction of the Battery Energy Storage Test (BEST) Facility has been completed, and it will soon begin operation as the focal point for joint industry-government work on advanced battery development. These batteries will be used to store electric energy generated at night to help meet midday demand peaks, thus avoiding operation of much more expensive oil-fired generators. By the mid-1980s, battery systems in the 5–10-MWh range will be tested under conditions expected for commercial operation. Personnel from participating utilities can receive hands-on experience in operating such systems and will be able to evaluate directly which systems are most suitable for their needs.

Transforming research results into practical applications by joint ventures is likely to become even more important as major new power generation technologies are introduced. The search for new ways to burn coal in a more efficient, environmentally benign manner is particularly critical. One of the most promising new technological options is the atmospheric fluidized-bed combustion (AFBC) steam generating system, such as the one used in the 20-MW (e) pilot plant nearing completion at Tennessee Valley Authority's Shawnee steam plant near Paducah, Kentucky. In this combustion process, sulfur dioxide emissions are controlled by burning coal in a fluidized bed of limestone at about 1550°F (843°C), a temperature that also minimizes the formation of harmful oxides of nitrogen. The need for costly postcombustion gas pollutant cleanup devices is therefore eliminated. EPRI is a major participant in TVA's 20-MW (e) pilot plant project, and TVA plans to follow this effort with a 100–200-MW (e) AFBC demonstration plant, operational in the late 1980s.

New approaches

Successful as these technology transfer efforts have been, EPRI's maturing research program requires that new approaches be tried. New policies and procedures are being established to enable the technical staff to assume transfer responsibilities that go beyond simply publishing research results. In particular, technical support in the utilities' first use of new equipment or computer codes is the responsibility of EPRI's technical divisions and, ultimately, the program or project manager. This person is uniquely qualified to aid first users of a new technology in adapting the products of research to a utility environment.

A recent example of such work is the two-year collaboration of EPRI personnel with Soyland Power Cooperative on the design, construction, and operation of a 220-MW compressed-air energy storage (CAES) plant. EPRI worked closely with Soyland in its formation of a coordinating committee of contractor representatives, preparation of engineering specifications, evaluation of vendor qualifications, and preparation of a list of bidders. In addition, EPRI furnished current technical information, coordinated engineering-economic studies, and developed acceptance test criteria for the plant.

An in-house technology transfer committee has been established to act as an information clearinghouse for EPRI. The committee is chaired by Wayne

Seden, manager of the Research Applications Program, which also prepares the annual *Research Results and Applications.* The committee includes representatives of each of the Institute's technical divisions, as well as staff members responsible for contracts, licensing, communications, technical information, member services, and research applications. The committee has four major responsibilities: to bring together members of various divisions for routine discussions of technology transfer; to identify and define pertinent policy issues for consideration by EPRI management; to share perceptions on various approaches to technology transfer; and to review recent experiences.

Continuing efforts are being made to include vendors in the sponsorship of joint research and demonstration projects. Willingness of a manufacturer to commit funds to a project is a good indication that the company seriously intends to bring the technology in question to market, once commercial feasibility has been established.

Renewed emphasis will be placed on using EPRI research facilities, such as NDE and BEST, as centers for technology transfer, since they represent the final, proof-test phase of R&D. The intent here is to minimize technical and economic risks associated with the commercial introduction of new technology.

In addition, field tests offer an opportunity for moving a technology quickly into widespread use. As an example, 25 instrumented racks of Polysil* insulators are now being field-tested in utility systems all over the United States.

Utility initiative

One of the most important new initiatives, which will require close collaboration between EPRI and individual utilities, is to make the position of technical information coordinator more effective. New approaches to this important task were the focus of a recent workshop in Dallas. An idea often heard in discussions of the coordinator's job is that he must be able to act as a technology broker within his company. Such a role requires intimate familiarity with a utility's problems, as well as its people, so that R&D results can be matched with pressing company needs.

A good coordinator is likely to be in midcareer, having spent a number of years with the company but not yet saddled with the heavy responsibilities of, say, a senior vice president. He should have some technical background, but he must be management-oriented. That is, the coordinator must be able to take a broad perspective of the company's needs, not a narrow, technical view.

Experience indicates that the best use of EPRI research has been made by utilities that have a well-structured system of internal communication to identify current problems and match them with appropriate technical solutions. The technical information coordinator is a key element of this system. Other important elements include the following.

□ Commitment from top utility management in expecting technical staffs to monitor EPRI results and put the most promising new technologies into practice in a timely manner

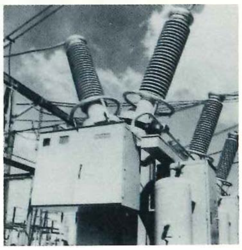
□ Active involvement in the industry advisory structure, as members of advisory committees are likely to be the first to know of coming developments

In a recent speech to the Pacific Coast Electric Association, EPRI President Floyd Culler emphasized the importance of technology transfer in helping utilities meet their most pressing needs: "The demand for electricity must increase to sustain the necessary increased economic activity in the United States. Electric power will certainly form the basis for the nation's reindustrialization. We will meet this demand if we match a well-deserved industry reputation for reliability with a new determination to accelerate technical progress. Research is the key; applying it is the challenge. I hope the utilities will find that EPRI R&D is their most important renewable resource. It can be, if research results are moved quickly to the power system. For EPRI programs to be successful they must be broadly applied throughout the electric utility industry." ■

This article was written by John Douglas, science writer, from information provided by Richard L. Rudman, director of EPRI's Information Services Group, and Wayne Seden, Member and International Relations Department. The material on the Dallas workshop was written by Ralph Whitaker.

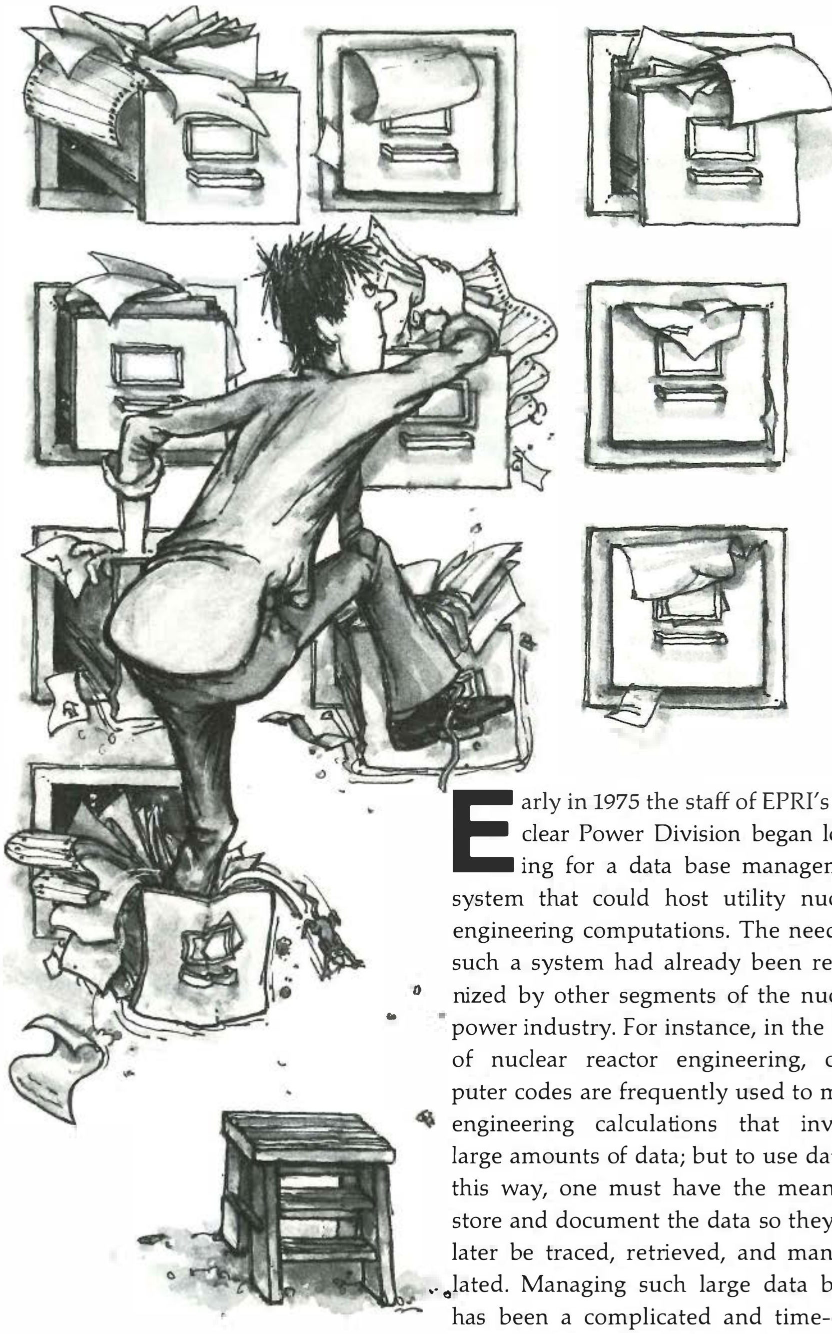
*Polysil is an EPRI trademark.

Installation of SF_6 puffer breakers for 230-kV fault isolation will mean significant savings and reduced maintenance for Carolina Power & Light Co.



DATATRAN fo

Engineers often have to rumma
on several different computers to g
engineering calculations. A s
helps the user quickly pick this info



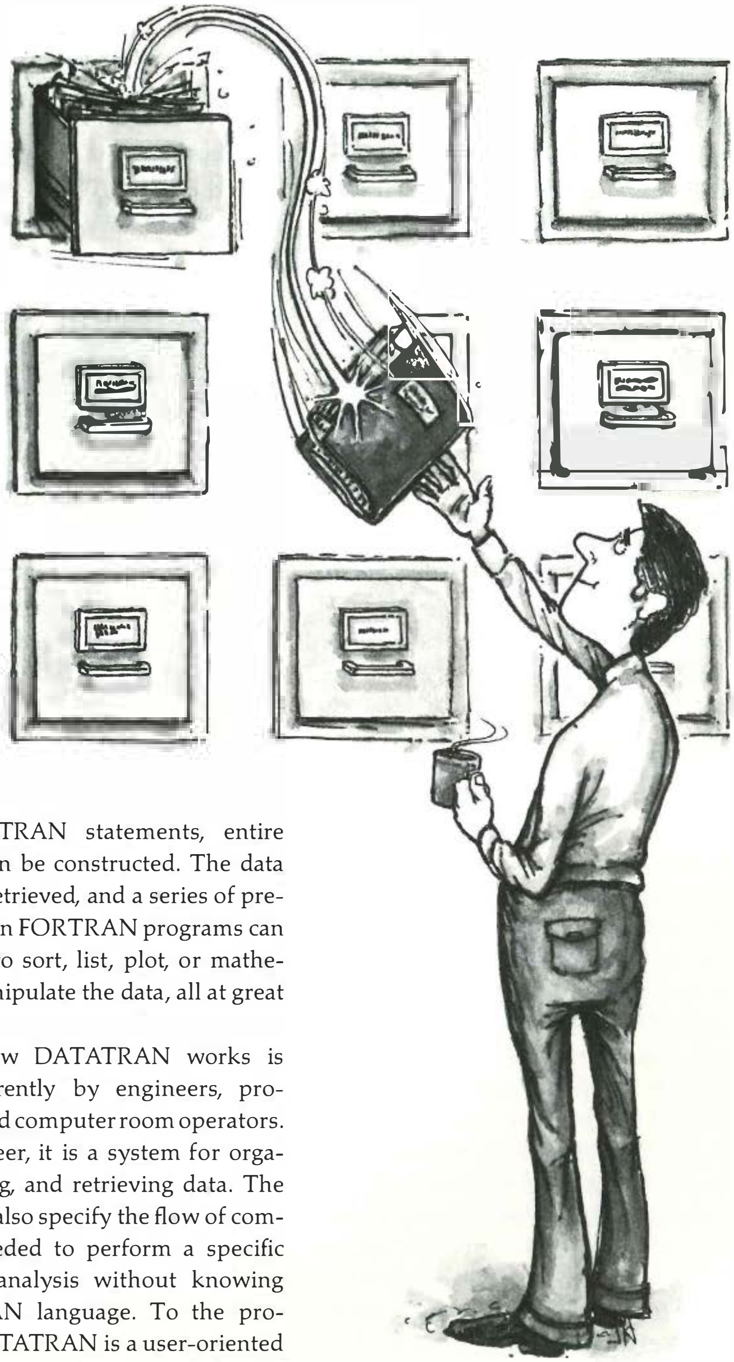
Early in 1975 the staff of EPRI's Nuclear Power Division began looking for a data base management system that could host utility nuclear engineering computations. The need for such a system had already been recognized by other segments of the nuclear power industry. For instance, in the field of nuclear reactor engineering, computer codes are frequently used to make engineering calculations that involve large amounts of data; but to use data in this way, one must have the means to store and document the data so they can later be traced, retrieved, and manipulated. Managing such large data bases has been a complicated and time-consuming procedure. Fortunately, computer systems exist today that can handle vast amounts of scientific data efficiently and at high speeds.

Such data manipulation implies sophisticated computer programs and programming. Yet the engineer who needs to access data rarely has time to do complex computer programming. A computer system is needed that can not only handle large amounts of complex scientific data but also build on an engineer's general knowledge of FORTRAN—the computer language commonly used in scientific work. The ideal system would allow the engineer to perform FORTRAN input and output painlessly. It would also be advantageous if the system's application programs could be easily moved and adapted to other computer systems.

"What was needed was a better highway to move data," says Harold Kopp of Technology Development Corp. of Santa Clara, California. Kopp draws an analogy between data manipulation and traveling across America in a car: travel would be slow if the only way to cross the continent was by a series of dirt roads. The driver would have to be a skilled map reader to always take the proper turns. But with a superhighway, the driver can go much faster and needs only basic map-reading skills. Kopp concludes that although a superhighway does not improve the inherent speed of the car, it

Easy Access

**rough a number of data bases
e information needed for complex
al computer software package
ion out of a tangle of irrelevant data.**



lets the car and the driver perform at top speed.

DATATRAN is a computer program that performs the role of a superhighway. DATATRAN was developed by Kopp in 1966 at Knolls Atomic Power Laboratory (KAPL) under the sponsorship of the Naval Reactors Program. At KAPL the need was to organize a data base for nuclear reactor calculations, to link computation programs to the data base and to each other, and to simplify the process of developing the input required to run these programs. By 1971 DATATRAN was used widely at KAPL. Even engineers with little computer training found they could access information and perform computations that previously could be done only by sophisticated computer programmers.

System function

DATATRAN is a computer software package—a language that can be integrated into the computer's regular FORTRAN language and give the computer system a more efficient means of managing large data bases. The DATATRAN language interpreter can translate simple DATATRAN statements into complex FORTRAN instructions, and by use of these DATATRAN statements, entire data bases can be constructed. The data can later be retrieved, and a series of previously written FORTRAN programs can be executed to sort, list, plot, or mathematically manipulate the data, all at great speed.

Exactly how DATATRAN works is viewed differently by engineers, programmers, and computer room operators. To the engineer, it is a system for organizing, storing, and retrieving data. The engineer can also specify the flow of computations needed to perform a specific engineering analysis without knowing the FORTRAN language. To the programmer, DATATRAN is a user-oriented operating system. It is an extension of FORTRAN that can be used to manipulate lists of data into and out of a data pool. To the computer operator, the

DATATRAN system looks just like any other computer job. At most engineering computing centers, a procedure has been devised in which only two or three program control instructions are necessary to run a DATATRAN job on the computer; to perform the same job with FORTRAN, several dozens of control instructions are needed.

"DATATRAN reduces the skill level required to use large computer programs," comments Kopp. "Engineers can link programs together with DATATRAN. Normally you need a programmer to do this." This linking capability gives DATATRAN the potential for handling most of the engineering computations performed by utility engineers. How fully this potential is realized depends in part on how widespread DATATRAN's use becomes throughout industry—like any language, DATATRAN's effectiveness is tied to its popular use. Kopp identifies the potential users as utility engineering staffs, equipment vendors, consultants, and contractors. For these people, DATATRAN would make possible an efficient exchange of data, the linking of codes developed at dispersed sites, and a uniform system for archiving different types of data—design, operating, and experimental. Use of DATATRAN would also mean a longer useful life for computer codes and require less effort to keep them up to date.

Installing DATATRAN on a computer system can take from a few days to a few months, depending on the system. It took Kopp only a few days to install DATATRAN on the CDC computer at the University of California at Berkeley because Kopp's experience with CDC equipment goes back to his KAPL days. For IBM computers and the advanced vector computers, the installation process takes much longer. When installation is complete, DATATRAN is thoroughly evaluated by a series of test calculations to ensure that DATATRAN itself is functioning and is interacting properly with the particular computer system on which it is installed. When all tests are satisfactorily completed, a two-day user-training seminar is given on DATATRAN. The students first learn to program DATATRAN and the matching FORTRAN statements and then practice saving and recalling data with DATATRAN commands. The classes are concluded when the students are able to link sets of data by DATATRAN.

One of the early users of DATATRAN was King House of Intermountain Technologies, Inc. Under a contract with EPRI, House used DATATRAN in the two-phase-pump performance studies by Combustion Engineering, Inc. The objective of this project was to obtain single- and two-phase-pump performance data over a wide range of steady-state and transient conditions. The test was done on a ⅕-scale model of a reactor coolant system primary circulation pump. The data were then used to develop an analytic method of describing pump performance for off-design conditions—the kind usually encountered in reactor coolant system analysis. Nearly 100 steady-state test points and 16 transient tests were ultimately conducted in the project, and about 10,000 pages of data were produced. The sheer bulk of these data reduced their usefulness. To simplify the analysis, the data were entered into a DATATRAN data base by giving each list of data a unique DATATRAN name that mnemonically documented and described it. The named lists were thus translated into DATATRAN data sets and were stored through the DATATRAN system as a part of the data base.

In the sense that FORTRAN is a language, DATATRAN is like a set of abbreviations, or acronyms, that can be used to streamline FORTRAN. For example, writes House, the name D.CE.PMP1/5.JUL79.EN.SCAN.P.SIS was given to one list of steady-state data. The name elements indicate these data (D) were produced at Combustion Engineering (CE) during the ⅕-scale pump performance tests (PMP1/5) and entered into the data base in July 1979 (JUL79). The data, expressed in English engineering units (EN) and recorded on the data scanner (SCAN), are pressure data (P) from the suction instrument spool (SIS).

The result of this unique DATATRAN name is that engineers who want to access the data from the two-phase-pump project need only know the number of the magnetic tape on which the information is stored and the unique data set name of the area of interest. The DATATRAN system handles the entire FORTRAN input and output by one DATATRAN statement. That is, the engineer does not need to know how many pieces of data are in the data set, how many records of data exist, where on the magnetic tape the data are written, or what the appropriate FORTRAN retrieval statements are.

System development

EPRI's interest in DATATRAN began in 1975, when the Nuclear Power Division began to speculate on how software and data base gathering projects might be carried out in the future. At that time, computer programs were being developed by one contractor, while data were being gathered and organized by a second. Moreover, both the software and data were often needed by third parties, such as utility engineers, other contractors, or EPRI staff. A way was needed to make the data and software transferable to and among all parties. The systems existing in 1975 that seemed to meet EPRI requirements were DATATRAN at KAPL and JOSHUA at Savannah River Laboratory.

In late 1975 EPRI began a pair of projects to investigate the adaptation of DATATRAN and JOSHUA to a utility environment. In a study performed at Rensselaer Polytechnic Institute, DATATRAN proved to have more advantages. Not only could DATATRAN codes be moved from one CDC to another, but also from CDC to IBM and back to CDC.

Key to the acceptance of DATATRAN by utilities was that DATATRAN would not interfere with other utility computer use. Having participated in the portability study at Rensselaer, the New York State Power Pool volunteered as a host site for testing an applications program. The Arizona Public Service (APS) load flow program was chosen as a test project. These tests were carried out during 1979 and early 1980. The objective was achieved; DATATRAN functioned in a nondisruptive manner at the utility computation center even though many programming changes were made to the APS load flow program in order to create a DATATRAN version. These changes were necessary to move data between the computer memory and the data pool. Although only 25 DATATRAN statements were used in the 9500 lines of modified APS program segments, many lines of FORTRAN programming had to be changed. This was easily done, in spite of the fact that the staff consisted of first-time DATATRAN programmers, who were given no more than the standard 16-hour training seminar. A preliminary DATATRAN version of the APS program required only half as much computer memory time and a quarter as much actual computer use time as the original version for a 450-bus electrical model.

In addition to the amount of time saved on the computer, DATATRAN's ability to move the data easily from one computer to another is quite valuable. "You have to understand the difficulty of getting on and off a computer to really appreciate DATATRAN," comments John Lamont, project manager in EPRI's Electrical Systems Division. Lamont, who is considering the use of DATATRAN in several electrical systems applications, says that with DATATRAN a user can move data around—within a computer, within a company, and even from utility to utility—providing each utility has DATATRAN on its computer system. When the original data are needed, one can easily retrieve them in the exact form in which they are wanted. Nothing is lost or has to be reprogrammed.

With data so easy to access, it becomes practical for utilities, contractors, and EPRI to share computer programs, thus saving everyone time and effort. "But," says Kopp, "in today's environment that doesn't happen as much as it could. The programmer today often can't use two programs without wading through irrelevant data." Extolling DATATRAN's ability to link data from one program to another, Kopp tells about a programmer at Yankee Atomic Electric Co. who had the job of organizing nuclear cross-section data from numerous computer programs. The programmer had been working on this for several months. DATATRAN offered him the structure he needed, and in one afternoon he completed the job he had been struggling with for months. This kind of data linking can also be done between different utilities as more of them install DATATRAN.

Brian Kirschner, a corporate planner at Yankee Atomic, agrees that utilities are in need of a concept like DATATRAN. "The ideal situation is to have a system like DATATRAN by which computer programs can talk to each other through a common data base structure."

Present and future use

Testing of DATATRAN in a utility computing center is under way at Yankee Atomic, Florida Power & Light Co., Virginia Electric and Power Co., Northern States Power Co., and the New York Power Pool. In this testing phase, EPRI is seeking to determine DATATRAN's usefulness for normal in-house engineering computer jobs and the kinds of interaction that occur between DATATRAN and utility computer centers. FP&L, Vepco, NSP, and NYPP have IBM computers, while Yankee Atomic has a CDC computer.

DATATRAN continues to be used by EPRI staff and contractors for data base applications, such as the CE $\frac{1}{5}$-scale pump tests, BWR turbine trip and stability tests, and PWR transient tests. Projects are being planned to reorganize pump data and critical flow data into DATATRAN lists and to provide a simple interface to some of EPRI's nuclear reactor safety analysis programs (e.g., RETRAN).

DATATRAN's usefulness in the electric utility industry will depend greatly on the results of tests being done at the four utility sites. Although DATATRAN has been installed at several locations, two unknowns still exist. One is the precise amount of manpower and time required to adapt DATATRAN to individual computer systems. The other is the extent of support and maintenance expertise required by users. In addition, the users need a mechanism for providing feedback both to DATATRAN's developers and to EPRI.

In response to these needs, EPRI has plans for work on a documentation clearinghouse and maintenance function. As computer technology evolves, it will be necessary to modify DATATRAN to interact with new systems; as new programs are written, it will be prudent to review the documentation of these programs in order to maintain consistency in form. The benefit of such a clearinghouse function is that any DATATRAN user will be able to quickly determine what a particular computer program does, what it must have as input, and what it produces as output. EPRI plans to support these functions.

DATATRAN will become important to the electric utility industry only if the library of DATATRAN programs grows. The KAPL experience showed that large engineering computer programs are more easily used by writing DATATRAN program statements to prepare input from a more engineering-oriented data list. DATATRAN's future will be determined by usefulness of this kind, and by how cheaply it can be maintained on the variety of computers used by the utility industry. ■

This article was prepared by Richard Karlgaard, science writer, from a paper by Robert Whitesel, General Public Utilities Corp., and John Lamont, EPRI, and a paper by G. A. Cordes, R. K. House, and G. A. Mortensen, Intermountain Technologies, Inc.

BWR Crack Control

Stress corrosion cracking in reactor piping has been a headache for BWR owners for over a decade. Cooperative research by EPRI and the Boiling Water Reactor Owners Group is providing the remedies to bring this problem under control.

During September 1974, a monitoring system at the Dresden-2 nuclear power plant at Morris, Illinois, recorded an increase in water leakage into the dry well that seals the reactor vessel from the rest of the containment building. The plant, owned by the Commonwealth Edison Co., was promptly shut down, and subsequent inspection revealed two cracks in the 4-in stainless steel piping of the recirculation bypass loop. The defective pipes were replaced, and Dresden-2 was put back online.

There was no hazard associated with the leak at Dresden-2, but General Electric Co., designer of the reactor, routinely alerted operators of similar facilities, and the Nuclear Regulatory Commission (NRC) ordered additional piping inspections. Nevertheless, the shutdown of Dresden-2 marked the beginning of a series of events that eventually would bring about the organization of the Boiling Water Reactor Owners Group and the establishment of a $43.8 million joint EPRI–BWROG research effort.

Stress corrosion cracking, the kind that occurred at Dresden-2, was not particularly unusual in BWRs—at least, not in older plants. But Dresden-2 was a new design, and the plant was only four years old. Moreover, a crack was found in piping at Dresden's sister plant, Quad Cities-2, only a few days after the Dresden-2 shutdown.

In October 1974 piping cracks were found at two Japanese BWR facilities. By the end of January 1975 cracks had been reported at three other plants, and the number of cracks found at Dresden-2 had risen to 12, some of which were in the core spray loop system.

In 1978 several large cracks were found in piping at the Duane Arnold nuclear power plant in Palo, Iowa, and there were further instances of stress corrosion cracking in Japan and Germany.

By the middle of 1978 a total of 132 corrosion cracks had been found in BWRs throughout the world. Stress corrosion cracking—increasingly troublesome and expensive—had become a high-priority research item.

Corrosion cracking

Intergranular stress corrosion cracking (IGSCC) had been a problem to metallurgists and corrosion engineers even before it started to show up in BWRs in the mid-1970s. Stress corrosion cracking occurs primarily at welded joints of type-304 stainless steel, a standard grade of stainless that is in wide industrial use. IGSCC was not uncommon outside the nuclear power industry; however, in other applications the affected pipes were relatively easy to repair or replace, and there was less incentive to determine causes and find remedies.

A. David Rossin, formerly director of research for Commonwealth Edison and chairman of the BWROG Technical Committee, who is now director of EPRI's Nuclear Safety and Analysis Center, elaborates, "Pipe cracks had previously developed in power plants, refineries, and laboratory equipment. So when cracks were found in piping at Commonwealth Edison's Dresden-1 plant in the late 1960s, there was little concern within the industry." Dresden-1 was the second large nuclear power plant to be built in the United States and the first to start commercial operation (1960). "We fixed the cracks at Dresden-1 by replacing the piping with a different grade of stainless steel," Rossin reports. At that time there was nothing to indicate that corrosion cracking was going to become a contributing factor in the downtime of many nuclear power plants in the United States and abroad.

Stress corrosion cracks are microscopic cracks that originate in stainless steel immediately adjacent to a weld. Unlike fatigue cracking, which is a result of repeated mechanical stresses, IGSCC is a result of electrochemical processes that break down the protective film on stainless steel. This phenomenon occurs principally in an area referred to as the heat-affected zone, an area that is sensitized by the welding process. The cracks start on the inside wall of the pipe and gradually lengthen and radiate outward, following the grain boundaries of the metal in the sensitized area; in severe cases, the cracks penetrate the pipe wall, causing leaks.

In BWRs the cracking occurs mainly in piping associated with the recirculation system. (PWRs are not subject to IGSCC because their water chemistry inhibits it.) The recirculation system pumps 1000-psi (6.9-MPa) water into the reactor core, where it is heated and converted to steam. "The cracks are very small and very tight, and they do not occur in the weld itself," explains Joseph Danko, EPRI–BWROG program coordinator. Danko states that about 35% of crack incidences manifest themselves as leaks; the rest are detected with ultrasonic testing equipment.

Corrosion cracking is not considered a hazard. The affected piping is located within the reactor containment building, and it has been determined that the defective pipes always leak before they break, thus ensuring detection and repairs before a safety problem can develop. But stress corrosion cracking of BWR pipes burdens the utilities in other ways. For example, the potential radiation exposure of repair personnel is increased, and the cost of unscheduled shutdowns is high—as much as $1 million a day just for replacement power from oil-fired plants.

Although cracking is not a frequent occurrence (about 1% of the welds crack), neither the welds most apt to fail nor the time when failure is most likely to occur can be predicted. Some welds crack a few weeks after installation, others several years later.

The EPRI–BWROG response

The 1974 leak (subsequently attributed to IGSCC) in the recirculation bypass line at Commonwealth Edison's relatively new Dresden-2 unit, as well as the rapid succession of other reported leaks, provided the impetus for an industrywide effort to resolve the IGSCC problem.

EPRI began a number of projects designed to isolate the basic causes of stress corrosion cracking, and General Electric Co., designer of all BWRs in the United States, undertook a comprehensive study of its own. The General Electric investigators concluded that unusual residual weld stresses were a key factor in the stress corrosion cracking that was being encountered. Because the cracks were limited to small pipes (diameters of 10 in or less) and because repair times were relatively short (two or three weeks), the utilities decided to handle the cracking problems as they occurred at operational facilities. However, steps were taken to provide fixes at plants under construction that were committed to using conventional stainless steel.

At this point, considerable knowledge had been gained about stress corrosion cracking, and the first remedies were beginning to take shape. It was known, for example, that three conditions had to be present before IGSCC could occur; moreover, the absence of any one of the three would prevent IGSCC. The conditions are tensile stress in the welded joint, sensitized metal adjacent to the weld, and an environment conducive to cracking. It was also thought that IGSCC was limited to pipes with diameters of 10 in or less.

Unfortunately, the corrosion cracking problem was soon to become more complicated, its potential consequences more severe, and thus its solution more urgent. Two 12-in-diam pipes—one in Japan and one in the United States—developed stress corrosion cracks. Even worse news came out of Germany. Both ends of a 24-in recirculation line in a KRB unit in Gundremmingen were found to be severely cracked. Although the German reactor was an old one (similar in design to the Dresden-1 plant), the report was disturbing because pipes with diameters larger than about 10 in had previously appeared to be free of IGSCC.

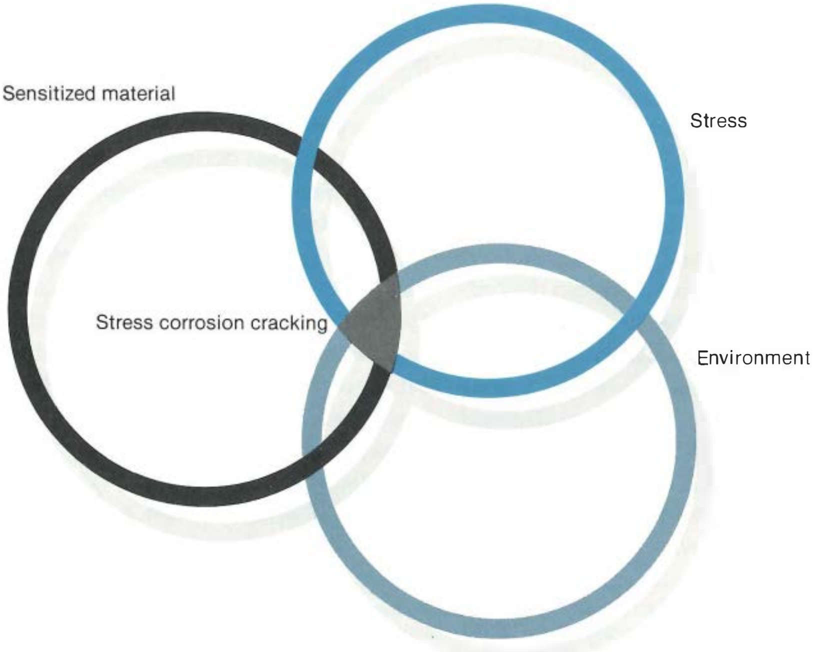
The implications of the cracking of large pipes were serious. It was bad enough to take a plant off-line for two or three weeks to make emergency repairs to a 4-in line, but the replacement of larger pipes could shut a plant down for several months. Besides the enormous cost of an extended shutdown and the increased radiation hazard for repair personnel, there was concern about public response to a technical and economic problem that the media were portraying erroneously as a safety issue. "Nuclear power is a controversial technology," comments Rossin. "We have enough real problems without adding fictitious ones."

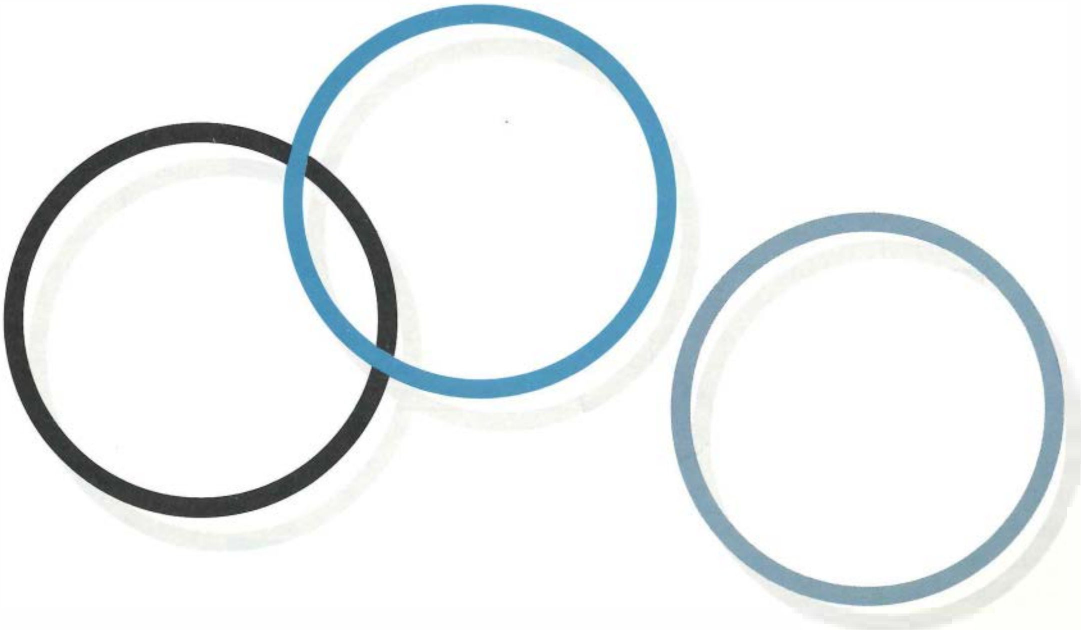
More than any of the other instances of stress corrosion cracking, the German incident served to unify the group of BWR owners. "It told us that instead of getting our group together periodically to exchange information, we had to move decisively to solve the cracking problem," Rossin reports. BWROG was organized by 24 U.S. utilities in October 1979. (Later, 11 others from Sweden, Switzerland, Finland, Italy, Spain, Taiwan, and India would join.) Even before that date, however, the BWR owners had negotiated with EPRI for help in putting together the basic structure of an extensive research program that would promise effective control of a problem

Three conditions must exist simultaneously for stress corrosion cracking to occur: sensitization of the material (generally through welding), stress, and an interactive environment.

Remove any one of the three conditions and the cracking problem is elim-inated. Remedies are thus tailored to these conditions.

REMEDIES





Sensitized Material	Stress	Environment
Solution heat treatment	Induction heating stress improvement	Reduction or removal of impurities
Corrosion-resistant cladding	Heat-sink welding	Oxygen reduction
Use of type-304 and type-316 nuclear-grade stainless steel	Last-pass heat-sink welding	

that was becoming increasingly important to the industry.

The research project that was needed would cost more than EPRI could support by itself, but in anticipation of formal ties with the owners group, EPRI boosted its spending on IGSCC research from $3 million in 1978 to $10.9 million in 1979. Once the four-year, $43.8 million joint EPRI–BWROG program was formally started in 1980, EPRI's commitment was cut back to $3 million a year.

Research objectives

The EPRI–BWROG project had three objectives: to determine the causes of the stress corrosion cracking, to develop remedies, and to get those remedies into the field.

Stress corrosion cracking in stainless steel pipe was known to occur when combinations of stress, water conditions, and sensitization of the steel near welds work together to cause cracks to grow. The key to the problem-resolution phase, drawn from earlier work at EPRI and elsewhere, was the development of a model of these three conditions. The relationship can be illustrated by three overlapping circles; cracking is likely to occur only when all the conditions are present—where all three circles overlap. It follows that eliminating one of the elements or reducing it below some critical threshold would inhibit or prevent corrosion cracking.

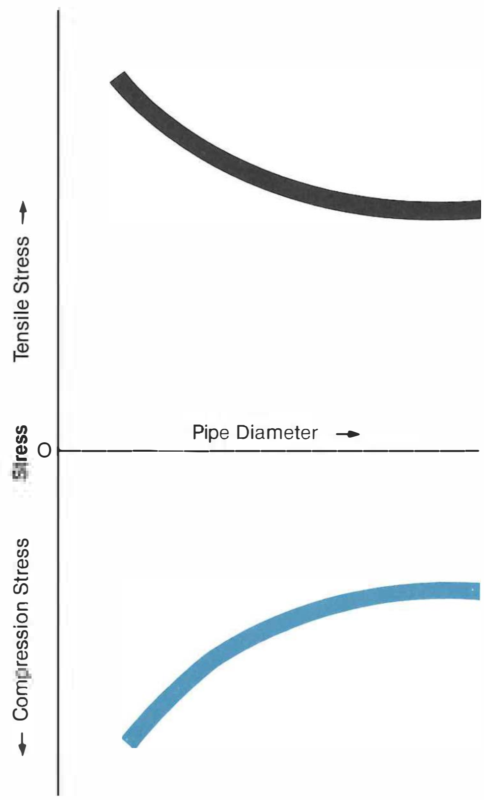
It should be noted, of course, that the model is an oversimplification of a complex relationship; for example, the relative sizes (the importance) of the circles would not always be the same, but would vary from situation to situation. Karl Stahlkopf, director of the EPRI Nuclear Power Division's Systems and Materials Department, notes that those circles are not nearly as precise a representation of the problem as they might appear. "They look nice in a model, but in the real world those lines are not so clear. In fact, they are very, very fuzzy," he explains.

Because sensitization characteristics can be controlled to some extent by changing the chemical composition of the alloy, sensitization was the first of the three corrosion cracking conditions to be attacked.

It is chromium that makes austenitic stainless steel "stainless," or more accurately, resistant to corrosion. When steel is welded, however, the heat imparted by the welding process causes some of the chromium atoms to migrate and form clusters of chromium carbide, thus effectively reducing the chromium content from about 17% to less than 12% at grain boundaries. This leaves small areas—sensitized areas—of chromium-depleted metal near the weld that are susceptible to corrosion because their chromium content is below the effective minimum. It is important to note that once begun, the sensitization process may continue at a very slow rate for a long time (perhaps as long as 10 years), driven by nothing more than the heat from normal reactor operations.

Sensitization problems can be virtually eliminated in the case of newly manufactured pipe by slightly lowering the carbon content of the steel and adding nitrogen. The resultant alloy, called nuclear-grade stainless, is available in both

Residual stresses in welded joints can be relieved by converting tensile stresses on the interior of the pipe wall to compression stresses. Three methods of altering these stresses are heat-sink welding, last-pass heat-sink welding, and induction heating stress improvement. Residual stresses decrease as pipe diameter increases.



type-304 and type-316.

There are at least two ways of desensitizing new pipe (after manufacture but before installation) or used pipe that has been disassembled. In one process, called solution heat treating, the welded area is desensitized by placing the welded joint in a furnace and heating it to 1950°F (1065°C). This dissolves the chromium carbide particles back into the metal grain. The second technique, application of corrosion-resistant cladding, involves putting a lining of weld metal inside the pipe before the joint is welded.

Tensile stress, another of the necessary conditions, has also been attacked in several ways. Because a weld bead contracts as it cools, a residual stress is created on the edges of the welded metal. Residual stress was a well-known phenomenon, but the magnitude of those tensile stresses and the ways in which they could interact with the other two corrosion conditions (sensitization and environmental conditions) had been less clearly understood.

There are several ways of relieving residual stresses in welded joints, all based on the principle of converting tensile stresses on the interior of the pipe wall to compression stresses—that is, causing the stresses to act in a direction that tends to press the joint together rather than pull it apart.

Heat-sink welding (running cooling water inside the pipe while the joint is being welded) and a variation of that process, last-pass heat-sink welding (in which the cooling water is used only on the last welding pass), both alter the residual stresses as described above. A third method, induction heating stress improvement (IHSI), has been developed by the Japanese. In this method, which is used after the welding is complete, the exterior of the pipe is heated while cooling water flows through the inside. Although IHSI is a more expensive process than either of the heat-sink methods, it is the only method developed so far that can be used on installed piping in an operating nuclear plant.

All these sensitization and welding-stress remedies were introduced last year and are being used by the utilities. NRC has stimulated interest in using the new alloys by extending its required inspection cycle from 80 months to 120 months for facilities in which the new approved materials are used. Eighteen utilities have shifted to the new alloys, and two that are building new plants scrapped the standard type-304 stainless piping that had been bought and replaced it with nuclear-grade metal. Sixteen others are using corrosion-resistant cladding techniques and solution heat treatment. These last two desensitization methods have been completely accepted by NRC, and credit for relief of augmented in-service inspection provided. The heat-sink welding remedies have not yet received this credit.

The third corrosion condition (operational environment) has proved to be the most difficult of the three to alter. Unlike PWRs, which use extensive water treatment, BWRs operate with high-purity water. It has been found that at BWR operating temperatures, as little as 200–300 parts per billion of dissolved oxygen in the water can act as a corrosion catalyst if sensitization and tensile stresses are present. Ways of eliminating the dissolved oxygen are being developed here and abroad (e.g., adding hydrogen to combine with the oxygen to form water), but none of them is operational. In addition to the dissolved-oxygen problems there are other water contaminants that must be dealt with—chlorides leaking from the coolant side of the condenser system (often seawater) and resin, which sometimes migrates from the water purification system itself.

Research results

By April 1981 the total count of cracking incidents at BWR facilities had increased to 254. But the EPRI–BWROG program is nearing the end of its second year, and containment of the problem seems to be at hand. Moreover, the remedies already developed hold the promise of fulfilling another objective, that of providing repairs that will last the 40-year life projected for nuclear power plants. In addition, advanced testing procedures will soon make it possible for utilities to predict which welds are most likely to fail and to estimate their remaining service life. For example, EPRI is completing work on an automated, microprocessor-controlled ultrasonic testing system called the adaptive learning network. This system will make it possible to detect and measure interior cracks more accurately and to reduce substantially the radiation exposure time of repair personnel. The first field model of the adaptive learning network is scheduled for testing before the end of the year, and the unit should be available to utilities in 1982.

A portion of EPRI's newly completed $4 million Nondestructive Evaluation (NDE) Center in Charlotte, North Carolina, has been reserved for pipe-remedy applications and technology transfer activities related to the BWROG project. The prime objective of the NDE facility is to put research results to work at the utilities as soon as possible.

The nuclear power industry has come a long way since the 1974 incident at Dresden-2. Rossin expresses what the program means to the owners, "The main thing from the owners' point of view is that even though they will still have some occurrences of pipe cracking, they know the cracks are not a safety problem. Outages can be minimized and repairs can be made with a high degree of confidence that the same kind of problem won't occur again."

Summing up for EPRI, Karl Stahlkopf comments, "We feel we understand the problem and we know how to mitigate it." But he adds, "We still have a lot of confirmatory research going on; we want to make sure we don't have an unforeseen problem that will show up five or six years down the road." ■

This article was written by Richard Immel, science writer. Technical background information was provided by Karl Stahlkopf and Joseph Danko, Nuclear Power Division.

PROFILE

Robert Sproull: Seeking the R&D Target

The question of where to focus R&D attention is just as important as how well the work is done. Useful perspective is often provided by those outside one's own field or institution, says this university president and physicist, who now chairs EPRI's Advisory Council.

Something is revealed about the city, the institution, and the man when Robert Sproull picks up a visitor at the Rochester, New York, airport, drives to the nearby campus, and leads the way—two steps at a time and talking over his shoulder—to his second-floor office as president of the University of Rochester.

This is an informal man, an energetic man, a man of many interests living and working in an institution and a community large enough to challenge him but small enough for his responses to be visible during his time.

Robert Sproull has been at Rochester for 13 years: 2 as vice president and provost, 5 as president, and 6 more as both president and chief executive officer. Sproull's time with EPRI is over 4 years, the period of his service on the Institute's Advisory Council, which he now chairs during a 1-year extension of his 4-year term. The 25 Council members are drawn from a wide range of U.S. businesses, professions, and interest areas. They are appointed by the Board of Directors, not to represent specific constituencies, but to bring many viewpoints to bear on the energy issues seen by EPRI's directors, management, and members.

The need for perspective

Sproull emphasizes that the Council's advice doesn't extend into the substance of R&D programs and their direction; that is the province of another group, the Research Advisory Committee. He finds a metaphor useful in distinguishing the two groups' roles and capabilities. For Sproull, the methodical planning, conduct, and evaluation of R&D represent EPRI's brain at work, fully attentive to its tasks. "But what decides whether you're going to put attention on this or that? What gives the brain its perspective? That's the mind. And the Advisory Council serves to some extent as EPRI's mind, in the sense that we can tell EPRI, 'Look, *this* is a terribly important subject.' It's a question of where the Institute's attention is, not how the R&D is handled or what the final answer turns out to be."

As he considers technical subjects today, especially the energy issues he deliberates with his Advisory Council colleagues, Sproull is harsh in assessing his own qualifications. "I'm just not that much of a professional any more. I used to be, but I'm not now. My contribution is to stand off a little bit and look at all sides." For example, Sproull recalls a Council meeting where EPRI President Floyd Culler talked about the chemical forms of radioiodine as it would evolve from a nuclear power accident, appear in the atmosphere, be ingested, pass through the food chain, and so on. "I understood what he was talking about, but as to quantifying the problem and the implications of new chemical studies that show it to be nowhere as bad as we thought, I'm just no longer in a position to have a critical view whether Floyd is right or wrong. My guess is that he is right because he is a pretty sound character."

Character assessment is not a sufficient description of the Advisory Council chairman's role. Sproull says he tries to evaluate the professionals' points of view. "Because I can't criticize the actual numbers, I audit the interaction between the other Council members. It's a kind of second-order, once-removed contribution."

A move toward management

At 63, Sproull looks back on a 38-year career that includes 16 years of solid-state physics teaching and research, 6 years of research laboratory and agency management, and 16 years of university administration. Actually, it would be better to say that he draws on the experiences of that career; it is not Sproull's habit just to look back, although he says of his early teaching at Cornell University in 1946, "I had a bunch of absolutely superb graduate students. It's hard to be other than romantic and dewy-eyed about the whole thing."

It is fitting that Sproull should aid electric utilities in the R&D pursuits acknowledged to be of such high priority for ensuring future electricity service. Sproull's father was local manager for the utility serving his boyhood hometown in north central Illinois, and Sproull clearly remembers, at age 8, going out with his father after midnight thunderstorms, to check on interruptions, customer problems, and restoration of service.

Events of Sproull's academic and professional life were less symbolic and more substantive preparation for his work today for the university and for EPRI. After three years at Deep Springs College, a tiny work-study ranch school in the high desert of eastern California, Sproull graduated in physics from Cornell in 1943, establishing a connection that would endure for 25 years. He worked for RCA for three years, then joined the Cornell physics faculty as an assistant professor. He became a professor in 1956, director of the laboratory of atomic and solid-state physics in 1959, director of the materials science center a year later, and vice president for academic affairs in 1965.

The key event hidden in this chronology was Sproull's two-year leave, from 1963 to 1965, to direct the Defense Advanced Research Projects Agency (DARPA) in Washington, D.C. Sproull had by then done much to develop support (including federal contracts) for Cornell's physics research program and laboratories. In fact, he had developed a taste and a competence in R&D planning, funding, and management. Sproull prefers to recall, however, the way officials of the Department of Defense insisted that it was his turn to work the other side of the street, to do his time in Washington.

Setting a two-year limit on his government assignment was Sproull's way of ensuring ahead of time that his enthusiasm would not flag. That enthusiasm returns as he tells of DARPA's role, one of its major successes, and some of the practices that made it authoritative and responsive in R&D management.

Created just after Sputnik in 1957, DARPA had as one of its responsibilities the acceleration of space research, which up to that time had been done by the military services. Even after NASA came into being in 1959, DARPA remained because it was not limited by the mission of any military service branch and could provide central management when more than one military branch was involved. By 1963, for example, DARPA research had been responsible for a satellite system that gave the United States the ability to detect nuclear explosions anywhere in the world. Sproull is grateful for that achievement (before he was with DARPA, incidentally) because it gave the U.S. Senate confidence in ratifying the nuclear test ban treaty. "That ban," says Sproull, "was one of the greatest things in the postwar period because it started the business of talking with the Russians rather than just threatening to thermonucleate them, which is a terrible way to communicate."

Ideas from outside

Considering its purposes, DARPA's annual budget was relatively small (about $400 million in 1963, Sproull recalls), "so what we wanted to do was exert leverage on a bigger program." Sometimes the idea was to widen the scope of an R&D program being done by one of the armed services. DARPA's own contracts, Sproull explains, could go beyond the mission limits of the Army, Navy, or Air Force. At other times, the need was for a longer-term view, and DARPA's work would "stretch the service R&D sponsors—keep them out of just the current year and get them thinking 5 or 10 years ahead. And to some extent," Sproull adds, "it seems to me that is EPRI's role now."

Speed was another mark of DARPA's work. "If somebody had an idea and came in the morning, we would talk with him. If we thought we needed to do it, we could and did commit a million dollars before the close of the day." Sproull does not recommend that kind of speed for R&D contracts today. His point is that R&D managers must have the ability to perceive good new ideas and the willingness to respond to them.

Sproull is emphatic about the need to keep abreast of developments outside one's own organization. "We had a rule at DARPA. No matter who came in, when he left we wanted to have learned something—what was the most exciting development in his lab. Even if we couldn't support him, even if he was a super salesman who exaggerated everything, there was still something to be learned. That spirit is the thing that makes for good R&D management anywhere."

Conviction on this point carries over into Sproull's life today. He belongs to two discussion clubs in Rochester, informal groups of top executives who hear and criticize members' prepared talks on subjects close to their management roles. Two of Sproull's continuing interests, for example, are the need for corporate giving to higher education and what he sees as overregulation of federally sponsored research at universities. Aware of his own potential isolation and that of others in similar positions, Sproull says, "You think what you're doing makes sense, but you've just got to have criticism from associates you can trust, who aren't in the same business but have a somewhat similar scope or function. For me, it's a delightful way of retaining a little bit of perspective. Otherwise, I'd think I ran the university!"

Acquainted with Xerox Corp. executives in Rochester and aware that Xerox is one of EPRI's high-technology neighbors near Stanford University, Sproull has the modest vision of a "discussion club for top executives in the area, a place where people can say, 'The emperor has no clothes.' Your own staff can't say it, but to hear those different views is more important than anything else you can do to synchronize your In and Out baskets."

Innovative thinking is indeed central to R&D itself, and it is important that an institution's leaders not slide into ruts of undetected complacency or arrogance; at the same time, there is something to be said for orderly practice. Sproull believes the Advisory Council is conservative in this respect. In his view, the Council does not "throw its weight around too much because it is reluctant to upset something that is working."

There is also the matter of incomplete understanding. The Council simply does not know all that EPRI's management and staff know about an issue. For that matter, Sproull acknowledges that Advisory Council members drawn from utility regulatory commissions often insist, "The rest of you need to know more about the regulatory process."

In light of these circumstances, Sproull seems content that the Council does not conduct its meetings in strict parliamentary style. He speaks of consensus and persuasion as being more appropriate than recorded votes and formal recommendations. "I don't want to be mischievous or a source of pain to EPRI," he says. For the Council to risk that by its insistence on a point, it would first need to resolve the many viewpoints of its own members, Sproull concludes. "We aren't going in there and flail around until we've got consensus."

Deciding the R&D emphasis

When Sproull speaks of the Advisory Council as something of a "mind" for EPRI, he describes the role as one of suggesting where the Institute should focus its attention. One area that Sproull believes deserving of such focus by R&D management is the balance between the present and the future, between the short term and the long term.

Sproull's sense of technology issues and his own experience lead him to give priority to long-term R&D. He distinguishes between industry and government criteria, however, saying that "industry, which has to pay 20% per year for its money, ought to be thinking about short-term things, and the federal government ought to be thinking about long-term things." Such an allocation of effort, Sproull notes, fits well with the tradition of many utility regulatory agencies because the fruits of short-term industry-sponsored R&D clearly reduce utility (and ratepayer) costs or improve service reliability.

But Sproull points out that the real world is different right now, and it is more than just having a new administration in Washington. There has been continuous change in federal energy R&D perceptions, policies, programs, organizations, and budgets for several years. Sproull's point goes beyond the question of cause, which is partly politics and partly a matter of rapid changes in the availability and cost of energy resources and our knowledge about them. His conclusion is that EPRI needs to be more concerned with long-range questions simply because there is a need for continuity in that effort. He sees some of this showing up already in EPRI staff assessments of long-term national energy needs. In Sproull's opinion, the rationale is thoughtful and the numbers are thorough.

Last year an Advisory Council committee headed by Gerald Tape (council chairman at the time) urged more R&D funding by electric utilities, generally through EPRI. Although the report did not suggest timeframe allocations for R&D expenditures, it did acknowledge that over half of EPRI's present program responds to near-term needs, thus tending to squeeze out the funding of long-term projects. The Council committee recognized the urgency of such matters as Three Mile Island accident analyses, costly demonstrations of new technologies at virtually full scale, and capital funding problems that are pervasive among utilities. In fact, finance is another subject area that Sproull feels needs more attention.

Sproull finds pros and cons, incentives and disincentives for EPRI involvement in this subject. The Council became interested at its annual seminar when a management consultant detailed the generation planning study it had done for a utility. The gist was that the needed new power plants were financially feasible only if all environmental and rate matters were resolved favorably and exactly on schedule. Even then, the endeavor would compromise the utility's bond rating and entail higher-than-usual interest rates. The conclusion of both client and consultant was that the project should not be undertaken because some approval was certain to be delayed, causing the project to slip. Says Sproull, "I think everyone at the conference found that an extremely sobering thought. It had nothing to do with technology. It had everything to do with financing and the political and social arenas."

He recalls that the Advisory Council pursued the subject at a subsequent meeting. "We ended up a little frustrated—not only the Council but the EPRI staff—because we see this as a huge problem but one that we don't seem able to get our teeth into."

The need for renewal

As Robert Sproull discusses R&D management, he does not spontaneously turn to novel organization structures. But he speaks time and again, in different ways, of the need for professional renewal, for individuals and managements to seek out different viewpoints as a matter of professional integrity and responsibility. "When I was with DARPA, I worried about whether my staff was in Washington too much. We had arrangements so that they were out in the field a great deal." Sproull suggests three or four years as the limit for an unbroken term of sponsored research management. Otherwise, the best person gets stale. "To keep the thing vital, you need to have people changing roles."

Sproull himself has changed roles. Despite his 25-year loyalty to Cornell, he realizes that one reason he left was the determination not to retire from his alma mater. But he does not minimize the difficulty of the effort for an individual or institution to stay fresh. "There are all sorts of reasons why you don't do it. And it takes determination and conviction to find the way." ■

This article was written by Ralph Whitaker and is based on an interview with Robert Sproull.

"You think what you're doing makes sense, but you've just got to have criticism from associates who aren't in the same business."

Washington Energy Information

There is a wealth of information on energy in Washington, D.C., but without a resource guide, finding out whom to contact for what you need can be frustrating.

What is the installed generating capacity of the U.S. electric utility industry, and how has it changed over the past decade? How much energy per fuel source does the average American consume in a lifetime? What coal-related research is being federally funded, and what legislation is currently being considered by Congress?

Finding the answers to such questions can require a considerable expenditure of time and energy, particularly at the national level, where a wealth of energy information lies within various government and industry organizations. In Washington, D.C., by some estimates there are 20 federal departments and agencies, 3 congressional committees, 30 subcommittees, and nearly 100 trade associations that disseminate energy information. The key is to find the right person with the right information in this maze. According to Matthew Lesko, founder of Washington Researchers, an organization that specializes in information research, most information is sought and found by using the telephone, and it takes an average of seven calls to find the right answer.

The following guide lists some of the key organizations that disseminate energy information in Washington and describes the resources they offer for tracking down energy data.

DOE Resources

The Department of Energy provides a variety of energy information, including statistics, information on ongoing energy R&D, and materials of general interest.

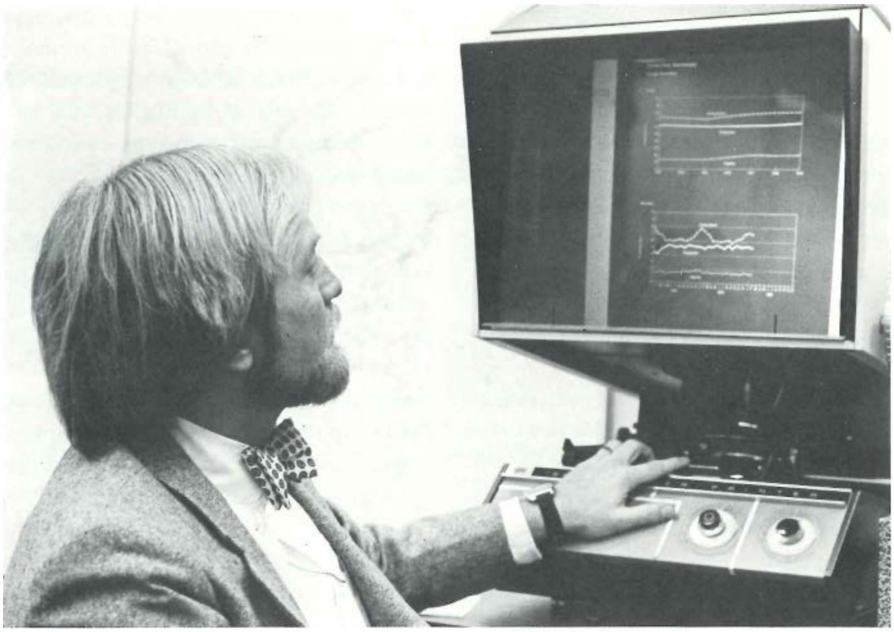
DOE's Energy Information Administration (EIA), which supplies Congress and the executive branch with energy statistics, economic analyses, and technical support, is an excellent starting point. EIA is also responsible for energy forecasting and analysis within DOE and prepares short- and long-term projections of energy supply and demand.

To handle questions of a statistical nature, EIA maintains the National Energy Information Center (NEIC). The center's staff of approximately 20 respond to written, telephone, and in-person inquiries regarding energy statistics and analysis, EIA publications, and reference data.

In responding to queries, the staff members refer to EIA documents. If they are unable to find an answer, they consult one of four in-house specialists in the areas of coal and synfuels, nuclear power and electricity, petroleum and natural gas, and renewables and energy legislation. A direct consultation with the appropriate specialist is a service the center tries to provide walk-in visitors. The odds are very good that if NEIC can't help you within the department, it can tell you where you can get the information in other government offices or in the private sector.

To help direct outside callers, NEIC maintains a list of contact people in the various DOE program areas, as well as in other agencies. This list, published quarterly as the *Energy Information Referral Directory* (DOE/EIA-0205), can be obtained from the Government Printing Office by subscription.

In addition to answering questions on energy statistics, NEIC issues a series of 18 energy fact sheets on such subjects as U.S. coal supply and energy use in nonresidential buildings. The information is carefully prepared, according to Thomas McCarley, an editor-writer at EIA. "We go through a strict process to check all the numbers and to make sure the information is written in language that the average person can understand. And every single fact sheet references an EIA publication."



McCarley

EIA also offers a free two-day course for those interested in learning about EIA's resources, including reports, information services, and the Federal Energy Data Index. Some of the publications discussed are *Monthly Energy Review, Weekly Petroleum Status Report, Coal Production Annual,* and *Electric Power Monthly.* Details on the course, which is offered every few months in either Washington or Albuquerque, New Mexico, are available from the course manager at NEIC.

DOE's Office of Public Affairs distributes nontechnical, general-interest publications on supply technologies and conservation. Questions of a statistical nature are referred to NEIC. Like NEIC, the public affairs staff can direct callers to the appropriate program areas as necessary. They also coordinate all DOE information activities, including appearances and speeches by DOE officials.

Another information resource within DOE, although independent of it, is the Federal Energy Regulatory Commission (FERC). The commission is responsible for regulating the interstate transportation and sale of natural gas and the rates and practices of oil pipeline companies engaged in interstate commerce. In addition, FERC regulates the rate and service standards for the sale of electricity at the wholesale level and issues licenses for the construction and operation of hydroelectric power projects not owned by other federal agencies. As part of its function, the commission requires regulated industries to submit forms on expenditures, income, and production levels. These forms are available in the public reading room at FERC headquarters in Washington.

A Guide to Public Information at the Federal Energy Regulatory Commission can be obtained by contacting FERC's Public Inquiries Branch. This guide describes available reports, forms, orders, and services, and tells how to obtain them. The Public Inquiries Branch is the reference point for agency publications, which include statistical reports, calendars of upcoming events, and speeches by FERC commissioners.

Another important source of information is DOE's RECON data base. The RECON system is housed at the Technical Information Center in Oak Ridge, Tennessee, which distributes energy data obtained from sources worldwide. Through the RECON system 39 energy files are currently accessible, ranging from the Energy Data Base, which contains more than 600,000 entries on unclassified scientific and technical energy information, to the Issues and Policies File, which includes more than 1300 citations of public statements, speeches, testimony, and press releases by the White House, DOE officials, and others.

In addition, RECON contains EIA's Federal Energy Data Index (FEDEX), which provides abstracts and standard bibliographic data for all EIA-produced documents. Graphs and tables excerpted from these reports can be searched individually. Also contained in the RECON system is the Electric Power Research File (EPD–RDIS), which compiles information on on-going and recently completed R&D projects conducted by the electric utility industry. Searchable data include major and minor keywords, titles, project numbers, descriptions, funding levels, contractors, reporting utility, research correspondent and phone number, and project duration.

Access to RECON is limited to DOE affiliates, federal agencies with energy-related functions, and state agencies with energy information responsibilities. For organizations that do not qualify for official access, the Western Regional Information Service Center at Lawrence Berkeley Laboratory (415-486-6307) will perform searches on the RECON system for a fee.

Some of the files contained in RECON, such as the Energy Data Base and the Electric Power Research File, are expected to be accessible through commercial online systems, such as Lockheed Dialog Information Systems (800-982-5838) and System Development Corp. Search Service (800-421-7229, West Coast; 800-336-3313, East Coast).

Other Federal Agencies

Other federal agencies provide energy information services in specific areas. Four key ones are the Nuclear Regulatory Commission (NRC), the Department of the Interior (DOI), the Environmental Protection Agency (EPA), and the Department of Commerce (DOC).

NRC's Technical Information Clearinghouse handles questions on nuclear regulation and licensing and NRC hearings. It can also provide a contact person within the commission to assist in answering specific technical questions. To improve the dissemination of nuclear energy information, the clearinghouse distributes *A Citizen's Guide to U.S. Nuclear Regulatory Commission Information.*

Another agency with energy interests is DOI, which has responsibility for most federally owned lands and natural resources. As part of its duties, DOI assesses domestic mineral, land, and water resources. Of specific relevance to the electric utility industry are the Office of Surface Mining, the Bureau of Mines, the U.S. Geological Survey, and the Bureau of Land Management, which perform oil, gas, and coal evaluations. Because of DOI's diversified nature, information requests should be directed to the Office of Public Affairs, which will refer technical questions or publication inquiries to the appropriate bureau.

At EPA the focal point for general information inquiries is the Public Information Center. EPA rules and regulations, court actions, and information on major enforcement actions are available from the center. It also handles some publication requests and can refer callers to specific program areas as necessary. To assist the public the agency has published *Finding Your Way Through EPA,* which lists the various agency offices, their functions, and key contact people. This pamphlet is available from the center.

EPA also maintains the Center for Environmental Research Information (CERI). Based in Cincinnati, CERI provides technical information on a range of subjects from health to environmental effects. One of its primary functions is to produce summaries of recently published project reports. These are available to the public without charge, and it is possible to get on a mailing list to receive announcements of available summaries.

DOC, through the National Technical Information Service (NTIS), maintains a data base on a variety of energy topics. The system contains files of government-sponsored R&D, as well as analyses submitted by federal agencies and their contractors on such topics as regulatory issues and technology applications. Of the new reports added to the NTIS collection each year, a third are energy-related. The NTIS system also contains the Energy Data Base and the Energy Abstract Newsletter, which publishes research summaries within three weeks of their receipt from the originating agency. DOE periodicals are also abstracted and indexed on the NTIS system.

Congressional Resources

Energy has become a pervasive issue on Capitol Hill. Three congressional committees—the House Science and Technology Committee, the House Energy and Commerce Committee, and the Senate Energy and Natural Resources Committee—and numerous subcommittees focus on energy, and others may stretch their jurisdiction to encompass an energy concern. The real challenge in the congressional maze is to determine which committees, subcommittees, and oversight committees are considering relevant energy legislation. One aid in accomplishing this is the House Legislative Status Office. This office can identify which House and Senate committees have jurisdiction over specific energy issues, what energy legislation has been formally introduced, and what, if any, action has been taken. Its computer files go back to 1973. The office will supply a free computer printout of the requested information.

Another tracking device is the annual committee calendar. Each committee is responsible for maintaining its own legislative calendar, which lists the members of the committee and its subcommittees; identifies the committee's jurisdictional responsibilities; lists bills, resolutions, and public hearings; and provides a subject index. The calendars are available from the appropriate committee's calendar clerk.

SOURCES OF ENERGY INFORMATION

DOE

Federal Energy Regulatory Commission
Public Inquiries Branch
Office of Congressional and Public Affairs
825 N. Capitol Street NE
Washington, D.C. 20426
(202) 357-8055

National Energy Information Center
Office of Energy Information Services
Energy Information Administration
EI-72, Forrestal Building
Washington, D.C. 20585
(202) 252-8800

Office of Public Affairs
Public Inquiries Branch
PA-341, Forrestal Building
Washington, D.C. 20585
(202) 252-5568

Technical Information Center
Box 62
Oak Ridge, Tennessee 37830
(615) 483-8611

Other Federal Agencies

Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161
(703) 557-4600

Department of the Interior
Office of Public Affairs
18th and C Streets NW
Washington, D.C. 20240
(202) 343-3171

Environmental Protection Agency

Center for Environmental Research Information
ORD Publications
Cincinnati, Ohio 45268

Public Information Center
401 M Street SW
Washington, D.C. 20460
(202) 755-0707

Nuclear Regulatory Commission
Technical Information Clearinghouse
Mail Stop 058
Washington, D.C. 20555
(800) 638-8282
(800) 492-8106 in Maryland

Congressional Resources

General Accounting Office
441 G Street NW
Washington, D.C. 20548
(202) 275-6241

Office of Technology Assessment
Public Communications Office
600 Pennsylvania Avenue SE
Washington, D.C. 20510
(202) 226-2115

U.S. House of Representatives

Energy and Commerce Committee
2125 Rayburn House Office Building
Washington, D.C. 20515
(202) 225-2927

Legislative Status Office
House Annex Building No. 2
2nd and D Streets SW
Washington, D.C. 20515
(202) 225-1772

Science and Technology Committee
2321 Rayburn House Office Building
Washington, D.C. 20515
(202) 225-6371

U.S. Senate
Energy and Natural Resources Committee
3104 Dirksen Senate Office Building
Washington, D.C. 20510
(202) 224-4971

Trade Associations

American Gas Association
1515 Wilson Boulevard
Arlington, Virginia 22209
(703) 841-8400

American Petroleum Institute
2101 L Street NW
Washington, D.C. 20037
(202) 457-7160

American Public Power Association
2301 M Street NW
Washington, D.C. 20037
(202) 775-8300

Atomic Industrial Forum
7101 Wisconsin Avenue NW
Washington, D.C. 20014
(301) 654-9260

Edison Electric Institute
1111 19th Street NW
Washington, D.C. 20036
(202) 828-7600

Electric Power Research Institute
1800 Massachusetts Avenue NW
Suite 700
Washington, D.C. 20036
(202) 872-9222

National Coal Association
1130 17th Street NW
Washington, D.C. 20036
(202) 463-2625

National Rural Electric Cooperative Association
1800 Massachusetts Avenue NW
Washington, D.C. 20036
(202) 857-9534

A researcher can also tap the three support offices on which congressional staffers rely heavily for pertinent and timely energy data: the Office of Technology Assessment (OTA), the Congressional Research Service (CRS), and the General Accounting Office (GAO).

OTA is an advisory arm of the Congress. Its basic function is to help legislators anticipate and plan for the long-term consequences of technological applications and examine the ways in which technology affects the public. One of OTA's three divisions devotes an entire program to energy technology. The Public Communications Office keeps the public and Congress informed of OTA's activities and available materials, including press releases, reports, briefs, and summaries. A request to that office will add your name to its mailing list.

CRS is a research and reference service offered by the Library of Congress exclusively for congressional members. Although it will not handle public requests for information directly, it will provide data for constituents through a congress-man's office. CRS produces a series of issue briefs that define issues, analyze their significance, review legislative highlights and recent congressional hearings, and provide a bibliography. There are numerous energy issue briefs in print, including ones on solar power, coal slurry pipelines, and geothermal energy. A complete listing is available from any member of Congress.

GAO responds to congressionally initiated requests for program audits and evaluations. It examines how efficiently federal resources are managed and controlled, and whether or not intended objectives are being achieved. GAO's Energy and Minerals Division is concerned with the economic regulation of energy, nuclear energy, electric power, federal energy resources, renewable resources, conservation, international energy policy, fossil energy supplies, and energy information.

From fiscal year 1980 to the present, GAO has produced more than 222 energy-related documents. The office maintains an in-house computer data base, and any GAO-produced report, letter report, or testimony can be searched by keyword. The GAO staff will provide a free computer printout of any available GAO materials on a specific energy subject.

Trade Associations

The energy-related trade associations discussed below represent another valuable source of information. An important part of their role as industry spokesmen is to maintain excellent communication channels with the public and to provide it with reliable information. They do this through magazines, newsletters, audiovisual materials, publications, speeches, and educational materials. To learn what resources are available, write the appropriate trade association to request a copy of its publications guide. Each association also has a library that is open to the public by appointment.

For questions about the electric utility industry, the appropriate trade association's public information office should be contacted: for investor-owned utilities, the Edison Electric Institute; for municipal utilities, the American Public Power Association; and for cooperatives, the National Rural Electric Cooperative Association.

One of the information specialties of the Edison Electric Institute, which represents nearly 200 investor-owned utilities, is electricity statistics. EEI's *Statistical Yearbook of the Electric Utility Industry* is an extremely helpful guide that presents data on the financial and operational aspects of the industry. These statistics include installed capacity, electric power generation and supply, and sales and revenues. Also of interest is the *Annual Electric Power Survey,* which lists current reserve margins, peak loads, and fuel use and future projections.

According to William S. Morris, the institute's vice president of communications, "EEI performs several vital communication functions, including prompt response and rebuttal of misinformation concerning important investor-owned electric utility issues. We are also a reliable source of technical data, as well as the spokesman for the investor-owned electric utility industry." As a means of informing the public of significant energy issues, EEI produces a decision maker series of publications on such topics as future economic growth, world energy, and acid rain.

The Atomic Industrial Forum (AIF) was formed as a nonprofit international organization interested in pursuing peaceful applications of nuclear energy. It is composed of more than 600 utilities, manufacturers, architect-engineers, financial and legal firms, consultants, and others. Through publications, brochures, conference papers, and other materials, AIF provides data on nuclear licensing and siting, R&D, safety and security, and waste disposal. It produces a series of 10 brochures on generic nuclear power issues, including radiation, reactor safety, and nuclear waste.

The American Gas Association represents some 300 gas transmission and distribution companies in the United States and Canada. Its public information office issues statistics on gas supply and reserves. A good source of information is the association's annual publication *Gas Facts.*

The American Petroleum Institute, the petroleum industry's trade association, can respond to inquiries about oil refining, production, and transportation; statistics and taxation; and exploration and environmental affairs. It issues periodic announcements of publications as well as an annual catalog. Two popular documents are *Facts About Oil* and *Two Energy Futures.*

The National Coal Association represents over 200 coal producers, sales and transportation companies, reserve owners, equipment manufacturers, and consulting firms. It collects, analyzes, and distributes coal industry statistics; forecasts production and consumption; performs studies on competitive fuel markets; and takes a special interest in any coal-related issues. Like the other trade associations, it maintains a communications service to handle outside inquiries.

In summary, there are three prominent sources of technical energy information in Washington: federal agencies, congressional committees and offices, and trade associations. This guide should serve as a good roadmap in determining who has the information you need. ■

This article was written by Ellie Hollander of the Washington Office.

Starr Calls for Regulatory Reform

Uniform risk assessment criteria are needed in regulatory decision making to avoid bias and ensure public safety.

Chauncey Starr, EPRI vice chairman, has called for a major restructuring of the nation's regulatory process that would include a uniform, comprehensive analysis of risks associated with all alternative solutions to a situation before decisions are made. Moreover, Starr believes this analysis should be performed independently of the conventional regulatory agencies to ensure objectivity.

Starr made the remarks in September at the International Meeting on Probabilistic Risk Assessment, cosponsored by the American and European nuclear societies. He said the current system is weighted against technology in general and new technologies in particular and the system actually may be increasing total risk to the public because of the failure to analyze all options completely.

Regulatory decisions, currently made on a case-by-case basis, use only limited quantitative analysis, which is heavily influenced by personal and special interests, public perceptions, and agency political interests. Although political and public views certainly have a place in regulatory decision making, Starr said they should not interfere with an objective professional analysis of solutions to a situation.

To make such an analysis meaningful, all alternatives should be compared against common criteria—something that is not currently done by regulatory agencies. For example, the Nuclear Regulatory Commission (NRC) considers low-probability, catastrophic scenarios in forming its design criteria for nuclear power plants, but it does not consider pollutant emission levels from the plants. In contrast, the Environmental Protection Agency is quite interested in pollutant levels when considering a coal-fired plant, but such low-probability events as a boiler explosion are not part of its analysis.

In general, according to Starr, the fact base on which decisions are made should be developed separately from the regulatory process. Then these objective findings should be transferred to the regulatory agencies for consideration along with the social and political issues involved in a regulatory decision. Adoption of these two separate procedures would allow regulators to provide "the most public safety that our politically determined allocation of resources will permit." Failure to do so, however, could actually increase the total risk to the public because of a phenomenon called risk transference.

Currently, uncertainty or regulatory discomfort with a technology is relieved by being more restrictive and more risk-adverse with that technology than would be warranted by the total facts available. As a result, risk is transferred from the technical system under consideration to other options that are not the responsibility of the decision maker. For example, when rules governing nuclear power plants are tightened, electric utilities tend more toward development of other alternatives, such as coal-fired power plants. But the NRC does not concern itself with the public risk issues associated with burning coal. Thus the agency is absolved of responsibility for the transference of risk. "The net effect of such a shift is to transfer the public risk from that of nuclear power to that of coal power, which may be larger," Starr said.

Similar examples can be found in virtually all high-technology decisions being made in this country. "Our regulatory decisions are made case by case in narrow sectors of technical responsibility without full consideration of the effects on the transfer of risk to other technologies, on the transfer of benefits to other sectors and regions, and on the welfare of the nation as a whole." ■

Generator Monitor Wins IR-100 Award

An on-line generator radio frequency (RF) monitor, developed by Westinghouse Electric Corp. under an EPRI contract, has been selected by *Industrial Research and Development* magazine to receive one of its IR-100 Awards, presented annually to the 100 most important new industrial products. The monitor detects abnormal RF signals from electric generators to warn of incipient damage that could lead to catastrophic generator failure. Such early detection is expected to save the utility industry millions of dollars each year in reduced generator downtime and repair costs.

In the past, utilities used heat sensors to monitor generators for problems; however, when arcing occurs in a generator, it can cause extensive damage long before enough heat builds up to trigger the sensors. According to Project Manager Gordon Shugars, the new device is based on the principle that a generator's RF emission profile changes significantly when arcing occurs. Such changes can be detected by attaching the new monitor to a generator's neutral lead. Shugars explains that this on-line operation is a significant improvement over conventional technology because it detects problems early, allowing repair work to be done relatively quickly and inexpensively.

The device, now being marketed by Westinghouse, has been tested on large generators belonging to several electric utilities in the United States. ■

Research Reviewed for House Staff Member

Orin Zimmerman (right), department director in the Energy Management and Utilization Division, explains details of EPRI's conservation technology research to Lee Wallace (left foreground), director of energy on the staff of the House of Representatives Science and Technology Committee. Wallace recently visited the Institute for an update on several areas of EPRI research. In addition to Zimmerman's discussion, Wallace received an overview from Joseph Prestele (left background), director of member and international relations, and an update on progress in radioactive-waste disposal from Robert Williams (right background), technical specialist in the Nuclear Power Division. Richard Zeren, director of EPRI's Planning and Evaluation Division, and Walter Esselman, technical director of engineering assessment and analysis, also participated in the briefings—Zeren discussed EPRI R&D priorities and Esselman presented information on utility growth projections.

CALENDAR

For additional information on the EPRI-sponsored/cosponsored meetings listed below, please contact the person indicated.

DECEMBER

1–3
Seminar: PCBs
Dallas, Texas
Contact: Gilbert Addis (415) 855-2286

9–11
Cable Materials Fire Detection and Extinguishment
Norwood, Massachusetts
Contact: Roy Swanson (415) 855-2024

JANUARY

11–14
Seminar: Reliability Design of Single-Pole Transmission Structures
Fort Collins, Colorado
Contact: Phillip Landers (415) 855-2307

26–27
Seminar: Environmental Issues in the Siting of Electric Transmission Lines
Dallas, Texas
Contact: Robert Kavet (415) 855-2590

FEBRUARY

8–11
Seminar: Reliability Design of Single-Pole Transmission Structures
Palo Alto, California
Contact: Phillip Landers (415) 855-2307

MARCH

15–18
Seminar: Reliability Design of Single-Pole Transmission Structures
Blacksburg, Virginia
Contact: Phillip Landers (415) 855-2307

R&D Status Report
ADVANCED POWER SYSTEMS DIVISION

Dwain Spencer, Director

EDS AND H-COAL LIQUEFACTION PROCESSES

EPRI is participating in the large-scale pilot plant testing of two coal liquefaction processes: Exxon Donor Solvent (EDS), developed by Exxon Research and Engineering Co. (ER&E); and H-Coal, developed by Hydrocarbon Research, Inc. EDS is an indirect catalytic hydrogenation process in which a catalyst is used outside the coal liquefaction reactor to hydrogenate the recycle solvent. H-Coal is a direct catalytic liquefaction process with particulate catalyst present in the coal liquefaction reactor. The objective of the tests is to accelerate the development of the two processes to commercial readiness.

The key element in this effort is the integrated R&D program in which bench-scale research, small-scale process development unit (PDU) operations, and engineering and design work are conducted simultaneously to support large-scale pilot plant design, construction, and operation. Large pilot plants are the major tools in the final test program that will provide the necessary information for equipment scale-up, selection of materials and equipment, special design criteria, and process performance confirmation. The capacity of the pilot plants was nominally set at 250 t/d of coal to keep the development cost as low as possible, while still ensuring that a commercial-size pioneer plant could be designed, constructed, and operated with an acceptable technical risk, based on the pilot plant results without a costly full-scale demonstration. Both pilot plants are now in place—EDS in Baytown, Texas (Figure 1), and H-Coal in Catlettsburg, Kentucky (Figure 2)—and the comprehensive test programs are well under way.

Exxon coal liquefaction pilot plant

The design of ECLP began in 1977 shortly after the execution of the cooperative agreement by ERDA (now DOE) and ER&E. The initial private sector participants were Carter

Figure 1 The Exxon coal liquefaction pilot plant at Baytown, Texas.

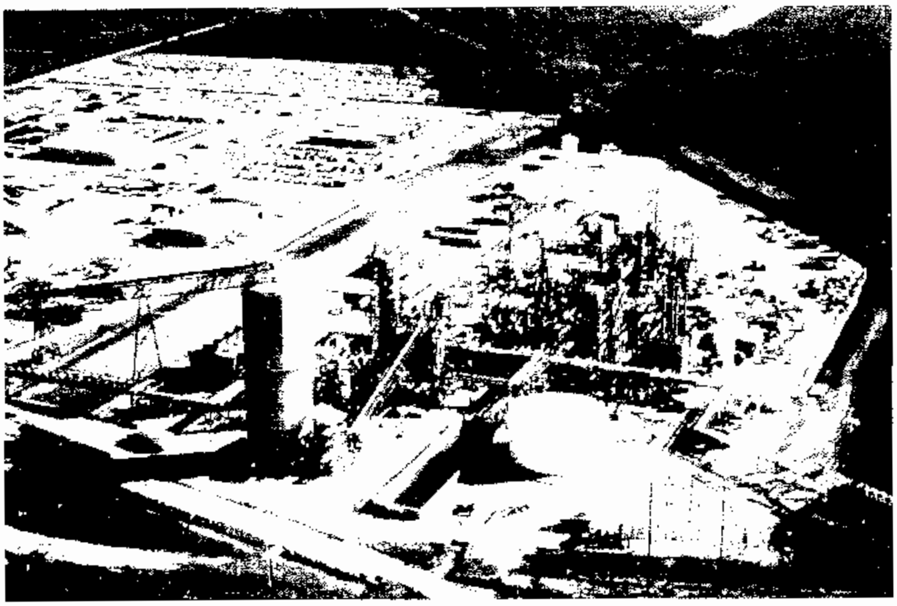


Figure 2 The coal liquefaction pilot plant for the H-Coal process at Catlettsburg, Kentucky.

Oil Co. (now Exxon Co. USA), EPRI, and Phillips Petroleum Co. New participants or sponsors have joined the project: Atlantic Richfield Co., Japan Coal Liquefaction Co., Ruhrkohle (West Germany), and AGIP SpA (Italy).

The mechanical completion of ECLP on March 21, 1980, was a significant event in the EDS project because it provided the large-scale integrated hardware. In addition to the smaller pilot plants (<1 t/d of coal), such large-scale hardware is required to bring the major components of the EDS process to commercial readiness.

The construction schedule and cost control at ECLP was exceptional: the plant construction, scheduled for 28 months, was finished only 4 months late. The cost of the plant was closed at $118 million, an increase of 7.3% over the original cost estimate of $110 million.

ECLP is an experimental plant and was specifically designed to obtain commercial design information in the following major areas.

- Process configuration to demonstrate an integrated, sustained operation of all process sequences that are incorporated in the EDS process, with the exception of liquefaction bottoms processing
- Liquefaction furnace engineering to demonstrate the operation of a commercial furnace design (e.g., determine coking tendencies, heat flux rates, flow patterns)
- Reaction engineering to model the fluid dynamics expected in a full-size commercial reactor design (The 2-ft [610-mm] inside diameter of the ECLP reactor and the 250-t/d coal feed rate were specifically selected for this purpose.)
- Rotating machinery to develop design data for pumps and compressors to be used in various services found in coal liquefaction
- Material of construction to gather corrosion/erosion information at commercial process and fluid flow conditions
- Slurry piping to confirm the adequacy of line sizing techniques and saltation correlations and to gather erosion data at commercial process and fluid dynamic conditions

In addition, operating procedures for all phases of operation, including startup and shutdown, are being developed and demonstrated during the operations with several coals. Overall process operability, reliability, and flexibility are also being demonstrated on ECLP in order to accumulate operating know-how on different coals.

The test program is currently scheduled for 24 months of operation on three coals: 12½ months on Illinois No. 6 bituminous coal from the Monterey mine, 6½ months on subbituminous Wyoming coal from the Wyodak mine, and 5 months on a lignite from the Texas Big Brown mine. Testing on each coal will consist of three operating periods: startup and shakedown; operation under steady and variable conditions; and plant turnaround, during which equipment will be opened and inspected for data required to judge the effect of various coals and process conditions on the plant components.

The 24 months of operation on three coals is an optimistic schedule. Its adoption was based on the 36-month operation plan initially requested by sacrificing all the built-in contingencies and some of the process optimization tests. There is a consensus among the participants in the project that both additional operation time and funds will be required to achieve commercial readiness if serious difficulties surface during the test program.

The first operation with Illinois No. 6 coal was conducted in the original version of the process: once-through operation at low-severity liquefaction conditions. This operation was completed on June 2, 1981, and was followed by a plant turnaround, which was finished in early July.

Table 1 summarizes the first operation. The targeted on-stream factors, 51% for the shakedown and 72% for the test period, were achieved during the operation with the first coal. High on-stream factors are essential in future operations for successful test program completion within the schedule and budget. Despite certain unexpected difficulties, sufficient time-dependent and spot-test data were gathered that permitted termination of the operation as scheduled.

Table 2 summarizes the Illinois No. 6 coal test program status. Data analysis is proceeding well and is scheduled for completion by the end of 1981. The analysis is expected to confirm that all but 16 of the 90 tests planned were completed satisfactorily.

Many of the mechanical and process problems were solved during the Illinois No. 6 operation. However, several important tests (in the slurry drying, slurry heater coking, and reactor engineering areas) were not completed during the first operation. Tests in these three areas will be carried out in the second operation. This run is using Wyoming coal feed and began in early August 1981, after construction of the bottoms recycle facilities was completed. The Wyo-

Table 1
SUMMARY OF FIRST ECLP TEST
(Illinois No. 6 Coal)

Operation	Date	On Coal (hours)	Off Coal (hours)	On-Stream (%)*
Shakedown				
Begin	6/24/80			
End	10/5/80	1245	1235	51
First turnaround	11/16/80		1000	
Plant restart/checkout	12/30/80		1045	
First test period				
Begin	12/31/80			
End	6/2/81	2658	1049	72
Total		3903	4329	47.4

*Percent of total hours.

Table 2
SUMMARY OF ILLINOIS NO. 6 COAL TEST PROGRAM

	No. of Tests
Tests scheduled	90
Tests started	80
Tests ended (data collected)	80
Data analysis in progress	80
Test objectives satisfied (to date)	28
Test objectives not accomplished	16

ming coal and a third coal, Texas lignite, will be run at increased-severity liquefaction conditions with bottoms recycle. The new operational mode is one of the major improvements resulting from the integrated R&D approach. It is expected to improve both the pilot plant performance and plant operability.

Prospects for successful completion of the development of the EDS liquefaction process with the ongoing test program are good. However, liquefaction bottoms processing, which is a critical step in the commercial application of EDS liquefaction, is not sufficiently addressed in the ongoing base program. Various alternatives, including partial oxidation and direct combustion of the bottoms in a hybrid boiler used as a process heater with steam cogeneration are being considered in an ancillary program to be implemented by the end of 1981. *Project Manager: Nandor Hertz*

H-Coal test program

The H-Coal pilot plant will demonstrate all essential processing steps except hydrogen manufacture from the vacuum tower bottoms. The objective of each planned test is to achieve 30 days of steady-state, lined-out operation. The first test is the syncrude mode with Illinois No. 6 coal, in which the net (commercial) plant product is an all-distillate synthetic crude oil. The residuum (vacuum tower bottoms) produced will be no more than what is required for gasification to generate process hydrogen.

An operation during February–April 1981 successfully demonstrated many key process features. The pilot plant was operated for 45 days with continuous coal feed to the reactor system. During the operation, 8370 t of dry-basis coal were processed at an average coal feed rate of 184 t/d and a maximum feed rate of 222 t/d. The test run demonstrated sustained steady operation of the slurry mix system. The ebullated-bed reactor remained trouble-free throughout the run, demonstating an oil-to-solids feed ratio of 1.75 and lower. Catalyst was routinely added and withdrawn to maintain desired catalyst age. The packing life in slurry charge pump service was improved. Other significant accomplishments were:

- The slurry feed heater operated well and at the end of the run showed no indication of coking in the tubes.
- The ebullating pump operated smoothly and showed no decrease in performance throughout the run.
- Slurry letdown valves, installed with Mogas block valves, changed out successfully without interrupting coal feed.
- Kieley-Mueller installations improved the life of slurry letdown valves.
- The seal life of the Lawrence slurry pumps showed dramatic improvement.
- The flaker system ran for sustained periods of time.
- The sour water stripping system showed marked improvement.

Table 3 shows the reactor product yields; the close correspondence with the 3-t/d PDU is impressive.

The operation was not wholly adequate, however. Additional operations will be necessary to meet all the goals. In particular, 30 days of fully lined-out operation were not achieved. Distillate product recovery from flashed reactor product was inadequate because mechanical and instrument failures prevented normal operation of the vacuum stripper. Although plenty of product was produced in the H-Coal reactor, the overall plant operation produced insufficient solvent to meet internal recycle requirements, and it was necessary to add extra petroleum solvent.

Sustained operation at design coal feed rate was not possible. The hydrogen purification system was inoperable; purge rates were so high that the plant capacity was limited by hydrogen supply. Control of the liquid level in the reactor effluent flash separator became unstable because particulate material accumulated.

Engineering and mechanical modifications, which were implemented during the June–July turnaround, are expected to correct the recognized deficiencies. The vacuum stripper column internals were modified, as were bottoms piping and valves. Operation at high vacuum will be made possible by vacuum system modifications. However, future addition of a preheater is anticipated because revisions are inadequate for high distillate recovery. The hydrogen purification system has been modified to reduce mechanical vibrations. Resolution of this problem has removed the hydrogen feed limitation.

Table 3
H-COAL PILOT PLANT PRODUCT YIELDS
(dry coal basis, 1981)

	March 28*		March 29*		3-t/d PDU	
	Coal (%)	Yield (bb/t)	Coal (%)	Yield (bb/t)	Coal (%)	Yield (bb/t)
C_1–C_3	10.96	—	10.94	—	10.68	—
C_4–400°F	22.71	1.66	20.94	1.53	18.74	1.40
400–975°F	23.89	1.46	22.26	1.36	28.33	1.62
975°F* residuum	21.62	0.94	25.83	1.06	19.00	0.86
Unconverted coal	3.47	—	3.48	—	5.78	—
Ash	11.22	—	10.88	—	11.51	—
Total		4.06		3.95		3.88

*Coal feed rate at 100% design.

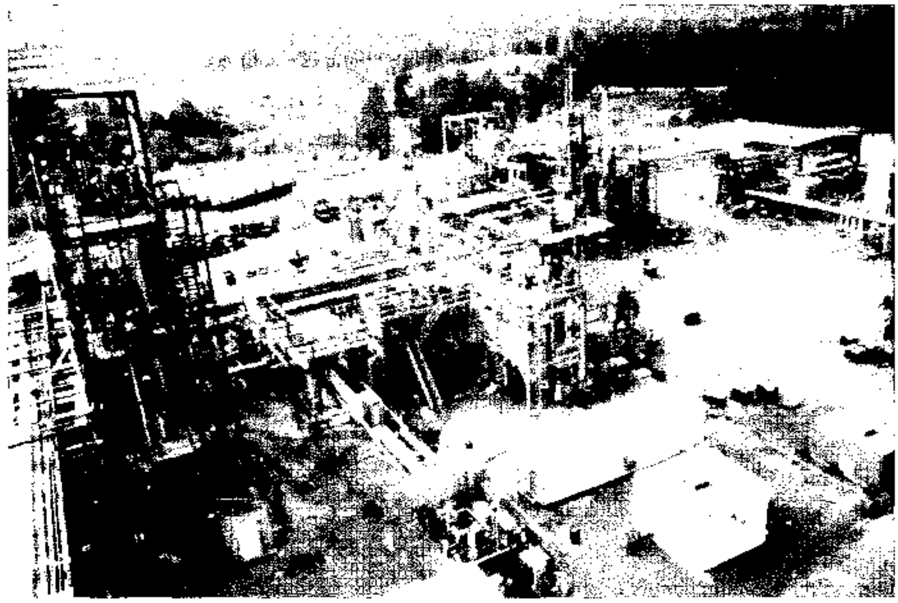
The reactor effluent separator was modified to prevent particulate accumulation. Sparge gas was introduced below the normal liquid level to supply agitation and prevent solids accumulation. The solids were not cohesive and did not form a massive deposit. Future operations will be followed closely to determine the prevalence of solids formation and growth. Normal operation in the absence of petroleum-derived makeup oil is expected to significantly reduce formation of solids.

Early results from the second major H-Coal operation, which began in August 1981, indicate that most of the major problems have been resolved. *Project Manager: Norman Stewart*

WILSONVILLE COAL LIQUEFACTION FACILITY

The Wilsonville facility is a 6-t/d integrated coal liquefaction unit located adjacent to Alabama Power Co.'s Gaston generating station (Figure 3). The original mission of the plant was to study several key steps in the production of solid solvent-refined coal (SRC). The initial SRC quality specifications restricted sulfur content to 1% and ash content to 0.2%. The process for achieving these specifications is similar to other direct liquefaction processes except that no catalyst is used, and the extent of the reaction is limited so that the principal product will be solid at room temperature. The scope of the Wilsonville program has recently been expanded to include the production of distillate fuels and low-sulfur residual fuel. This is being accomplished by coupling SRC production with catalytic hydrotreating in a two-stage liquefaction process. Early operations of the new hydrotreater, which was commissioned in May, have been very encouraging. SRC has been converted into distillate fuel and low-sulfur (<0.2%) residual fuel; good selectivity to boiler fuel production has been observed in that the concomitant yield of gas and naphtha was quite low.

Figure 3 EPRI's 6-t/d pilot facility in Wilsonville, Alabama, where advanced research on solvent-refined coal is being conducted.



In preparation for the two-stage liquefaction program, several improvements have been made in the SRC production process. First, the critical solvent de-ashing (CSD) process has been developed for removing ash from the product and for generating a vacuum residual recycle stream known as light SRC. Second, SRC production at low temperatures (750–780°F; 399–416°C) has been accomplished, using the light SRC recycle solvent. Third, the importance of using a high-quality startup solvent in the SRC process has been demonstrated, and a procedure for producing such a solvent has been developed. Fourth, an analytic test for monitoring solvent quality has been demonstrated and the results correlated with plant performance.

Critical solvent de-ashing

The CSD unit has been a part of the pilot plant operation for several years. Before installation of the unit, the product was de-ashed by filtration. In contrast to that mechanical separation process, CSD is a continuous chemical extraction process. It was chosen primarily because of its mechanical simplicity and the resultant savings in capital and operating costs. There were, of course, problems associated with CSD that had to be resolved before the potential savings could be fully realized. These included incomplete product recovery and possible de-ashing solvent losses.

These two problems have been substantially resolved. Product recovery can be readily increased by modifying either the composition of the de-ashing solvent or SRC composition. Early in the program the emphasis was on improving SRC composition by increasing the pressure and residence time in the reactor. Another technique was to use more powerful de-ashing solvents in the CSD unit. The best solution, however, is based on the observation that SRC composition can be beneficially affected by maintaining a high-quality recycle solvent in the SRC process. Recent Wilsonville runs have demonstrated that such a solvent can be achieved by using a good startup solvent and maintaining its quality by recycling light SRC.

Considerable effort has been devoted to confirming that de-ashing solvent losses are low. This is quite difficult at the pilot plant scale, where handling losses for processes of this type are always expected to be high as a percentage of feed. The same losses would be negligible in a larger unit. The task is thus not simply to measure the pilot plant losses, but to demonstrate that there are no irretrievable losses. The most critical potential problem areas, chemical reaction with the products and losses to the ash, have been eliminated.

Low-severity operation

A very significant part of the pilot plant program has involved efforts to reduce the severity of liquefaction operating conditions (temperature, pressure, and residence time). The key to this type of operation is the extensive recycling of light SRC.

The original incentive for attempting low-severity operation was to maximize SRC production while minimizing the production of low-boiling liquids and gas. Before light SRC was available, minimum conditions were dictated by the requirements of achieving recycle solvent balance and meeting sulfur specifications. It was theorized that light SRC could be used to make up deficiencies in the recycle solvent and that desulfurization could be accomplished more efficiently in subsequent processing.

The technique of recycling light SRC was first attempted with bench-scale equipment in 1979 by Conoco Coal Development Co. and Kerr-McGee Corp., the developer of the CSD technology (RP1134). The results of this program were very encouraging. The use of light SRC as a solvent supplement was proved in principle. One application with particular relevance for preparing utility fuels was low-temperature SRC operation (780°F; 416°C). Very efficient production of SRC was demonstrated at this temperature, and the yield of high-boiling liquid fuels was impressive. Hydrogen utilization was very efficient, with small gas and naphtha yields.

There were, however, several uncertainties in the bench-scale work that required resolution at a larger scale. Two of these involved apparent low coal conversion and low SRC recovery in the CSD unit. Theories were proposed to explain these results in terms of the nature of the small bench-scale operation. Work was subsequently undertaken at the Wilsonville pilot plant to verify these theories and to resolve another major uncertainty—whether light SRC recycling could be maintained in a steady-state operation.

Several runs have now been completed at Wilsonville that demonstrate the low-temperature reaction. It has been determined that both coal conversion and SRC recovery rates are at least equal to those achieved at high temperature. The yields are very desirable in that gaseous and low-boiling products are minimized. This results in the efficient use of hydrogen and the potential for product cost reductions. Also, yields of products in the turbine and boiler fuel range are maximized. Long-term steady-state operations were achieved. On the basis of these encouraging results, the low-temperature SRC production process will soon be coupled with the hydrotreater.

A side benefit of this work was realized when the solvent produced in the low-temperature operation was used as the startup solvent for a run at normal temperature. Plant performance was substantially improved, even when the original solvent had been replaced by the products from the high-temperature run after a long period of operation. Recovery in the CSD unit was increased by over 10%, and yield makeup was improved. Apparently the quality of the solvent determines the nature of the products that replace it. *Program Manager: Howard Lebowitz*

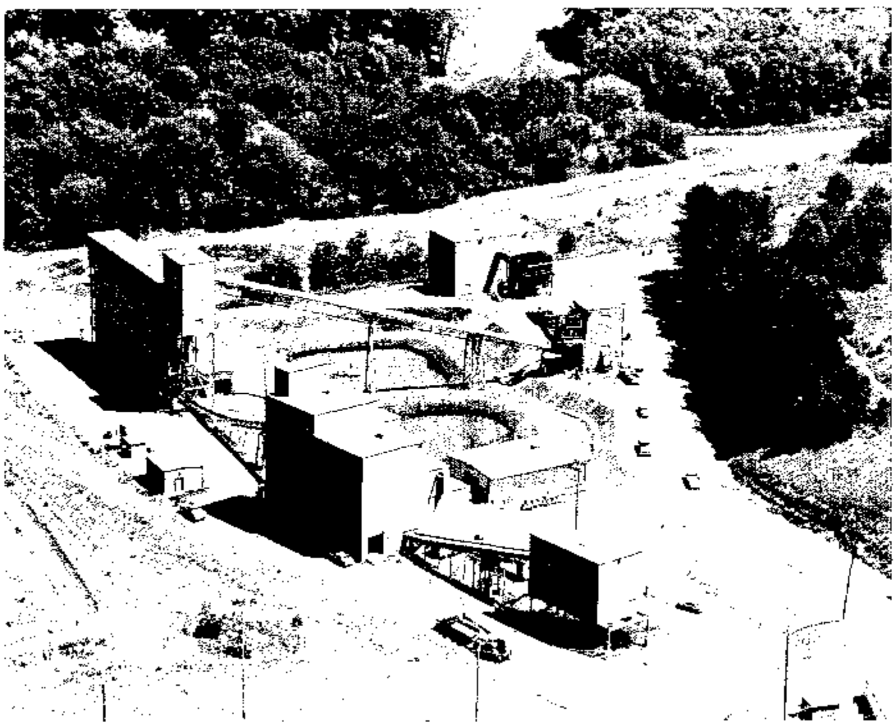
R&D Status Report
COAL COMBUSTION SYSTEMS DIVISION

Kurt Yeager, Director

COAL CLEANING TEST FACILITY

The Coal Cleaning Test Facility (CCTF), located near Homer City, Pennsylvania, started plant acceptance trials in July and began operation in September (Figure 1). The complex nature of the facility, which houses five flow sheets, novel instrumentation, and a process control computer in the test plant, contributed to the protracted startup schedule. In addition, the cleaning circuits, being much smaller than those in commercial plants, are extremely sensitive to minor changes in water flow. Diligent efforts by EPRI personnel, Roberts & Schaefer Co. (the detail design and construction contractor), and Kaiser Engineers of Pennsylvania (the facility operator) provided for a smooth transition from startup to operation. CCTF is receiving substantial interest. Tours of the facility have been conducted for representatives of EPA, DOE, Gulf Oil Corp., the West German steel and coal industry, and the Australian coal industry, as well as for interested utilities. This interest has been sparked by the unique nature of the facility and the resurgence of international interest in coal and coal cleaning.

Figure 1 EPRI's Coal Cleaning Test Facility is the nation's newest and most advanced coal-cleaning research, development, and demonstration plant. It will evaluate the cleanability of different kinds of steam coal and ascertain the best cleaning methods.



Conventional coal-cleaning systems (water slurry cleaning by gravimetric and surficial methods) reduce ash and pyritic sulfur. Ash removal of 60% and sulfur removal of 40% from run-of-mine coal is not uncommon in coal cleaning. The quality of clean coal and the effectiveness of cleaning are largely affected by the nature of the raw coal and the cleaning processes employed. The test facility will investigate the use of various commonly employed and commercially available processes on a variety of coals that represent the major national coal regions.

Although coal cleaning can reduce ash- and sulfur-loading in a boiler, cleaned coal has not been widely accepted by the utility industry—some estimates put current practice at about 30% of the coal burned. The main deterrent is the cost of cleaning, and the major component of the cost is related to coal lost to the refuse product streams. Coarse-coal cleaning systems are highly efficient from a recovery standpoint, but fine-coal (minus 28 mesh) cleaning systems are less efficient in reclaiming and washing burnable matter. Drying of fine coal, which can represent 20% of the feed stream, is difficult, and fines commonly contain 25% moisture. As a result, most fine-coal cleaning systems produce a product that is higher in moisture than run-of-mine coal, and using clean coal will result in a loss of boiler efficiency. Because cleaning and dewatering fine coal is relatively new, substantial improvement can be expected in this area. R&D activities at CCTF will concentrate on cleaning minus ¾-in coal, with major emphasis on the minus 28-mesh fraction.

Even with the drawbacks mentioned above, clean-coal use by utilities is increasing, as evidenced by the recent commissioning of Tennessee Valley Authority's Paradise coal-cleaning plant and American Electric Power's Windsor plant. Completion of Pennsylvania Electric Co. and New York State Electric & Gas Corp.'s Homer City coal-cleaning plant early next year will add to the list of utility-owned cleaning plants. Clean coal is also being used by the New England

Electric System at its Brayton Point plant, where the coal-oil boiler was converted to clean coal without the addition of scrubbers, and the environmental impacts are less severe than those experienced with oil.

The costs and benefits associated with the use of cleaned coal in new units has been investigated (EPRI CS-1622). Because sulfur removal by cleaning is much less expensive than stack gas cleanup and the revised New Source Performance Standards allow a credit for sulfur removal before burning, six of seven cases investigated in the study indicated a net benefit in favor of coal cleaning. There are also preliminary indications that using clean coal may improve unit availability. If a 1% improvement in availability is taken into consideration, all seven cases indicate coal cleaning is cost-effective. Although the study focused on new units, the methodology used to evaluate the impact of coal cleaning is also applicable to existing units. The majority of variables to evaluate the use of clean coal are coal- and site-specific in nature, and each utility must decide its course of action on a case-by-case basis.

CCTF can assist utilities that are considering the use of clean coal by performing evaluations of the cleaning process best suited to cleaning the particular coal to be used. As all coals react differently to cleaning, it is expected that utilities will perform flow sheet selection evaluations at CCTF. Large quantities of coal (over 100 tons) can be handled, washed, and analyzed, and substantial amounts of clean coal can be prepared for test boiler work.

Most cleaning plants are custom-designed for a particular coal, mining conditions, and the clean-coal quality and recovery requirements of the builder. The circuits and equipment used in CCTF evaluations are commercially available; therefore, sound predictions of full-size plant performance can be made with confidence on any coal processed. This aspect of CCTF (i.e., performing integrated flow sheet evaluations with pilot plant–size equipment) is unique and a departure from past practices of developing flow sheets based on a small sample (less than 1000 lb; 450 kg).

Eight base coals are being solicited from the utility industry: an anthracite, three high-rank bituminous, three subbituminous, and a lignite. These coals will be processed in one or more of the test facility flow sheets that are best suited for cleaning the particular coal under consideration. Cleaning system effectiveness will be measured, along with a full analysis of changes in coal quality. Analysis of the as-received and the cleaned coal and ash will result in a better understanding of the effects of coal cleaning on boiler design and operation.

A major criterion used in the selection of the base coals is their future availability. The base coals will be used as feedstock to novel coal-cleaning processes that eventually will be added to CCTF. The effect of coal heterogeneity on those performance comparisons will be reduced because a wide range of coal types will be evaluated. Also, the effect of cleaning system performance on different coal quality parameters can be determined.

Two committees have been formed to guide the R&D activities at CCTF. A subcommittee of the Coal Quality Program Committee was required to monitor research plans and accomplishments. The Technical Advisory Committee, consisting of representatives from the coal industry, commercial plant designers, DOE, and academic institutions, was formed principally to coordinate CCTF activities with their respective institutions. The first committee meetings will be held in December to review the first annual R&D detail plan.

Initial work at CCTF includes evaluation of the 54 solid and slurry samplers that surround the processing equipment. All samplers will be validated under a full range of processing conditions so that they can be relied on for the equipment and circuit performance evaluations to be conducted later on.

Sampler accuracy and bias will be ascertained and the samplers will be modified to correct deficiencies. As the CCTF samplers are installed in a wide variety of applications, the knowledge gained in calibrating and improving their performance will be valuable to the proper design and placement of samplers at boilers and coal-cleaning plants.

While sampler validation is proceeding, instrumentation performance evaluations will be made and process control strategies will be developed. The instrumentation currently installed is commonly used in other processing industries but requires demonstration in a coal-cleaning atmosphere. As with samples, instrumentation performance will be measured over a wide range of operating conditions, problems ascertained, and corrections made. The results of the work will be important to the proper selection and use of instrumentation for process and quality control of coal-cleaning plants.

On-line slurry ash analysis is also being investigated on a bench-scale level, and when completed, the equipment will be moved to CCTF for demonstration. When the instrumentation has been successfully coupled to the CCTF computer, on-line process control to optimize yields and minimize coal quality fluctuations will be demonstrated.

Before utility flow sheet testing or base coal processing can be accomplished, all equipment in the test plant will be tested under a variety of conditions. Equipment performance evaluations will be conducted on a local coal. The effect of equipment operating variables on performance will be evaluated so that a process can be modified to accept any coal. This work is planned for completion in the first quarter of 1982. At that time, utility flow sheet testing and base coal testing can begin. *Project Manager: Douglas Trerice*

R&D Status Report
ELECTRICAL SYSTEMS DIVISION

John J. Dougherty Director

POWER SYSTEM PLANNING AND OPERATIONS

Modeling generating unit operating conditions

The traditional models of generating units used in current computer programs for generator reliability are relatively simple. This simplicity came about by weighing the accuracy desired against the cost of conducting studies; the lack of accurate or sufficient data for more sophisticated models was also a factor. For some time now, it has been clear that these simple models neither track actual experience nor predict future performance with sufficient accuracy. Analysis of the problem has led to the conclusion that a number of operating considerations (e.g., spinning reserve, unit startup failures, and other factors that have traditionally been omitted in the simplified generator models) could be contributing to the less-than-satisfactory results. In addition, recent advances in simulation technology have made more sophisticated simulation acceptable in terms of time and cost.

In a project with Associated Power Analysts, Inc., three different models have been developed to incorporate operating considerations: a simulation model, a recursive analytic model, and a rare-event analytic model (RP1534). A simulation model called GENESIS provides a method of analysis that adds greater fidelity to many of the traditional assumptions in the calculation of reliability indexes. The model incorporates such operating considerations as the spinning reserve, unit startup failures, unit startup times, outage postponability, and planned maintenance outages. The performance of the GENESIS model has been validated against the historical data of an actual utility system and over a range of synthetic utility systems with various operating parameters; it is accurate for the analysis of single-area systems and should be a cost-effective tool for system planning and operations planning.

Two analytic models, the recursive model and rare-event model developed in this project, compete with a GENESIS simulation model of unit operating conditions in computation time and data requirements. Efficient computer programs for these models were developed, and they have demonstrated their ability to accurately compute a generating unit's reliability. There was close agreement between the results of analytic models and the GENESIS model in terms of reliability indexes.

The relative accuracy and computation efficiency of the GENESIS model and the analytic models will be presented, and prototype computer programs for both the GENESIS model and the analytic models will be available at the completion of the project in the first quarter of 1982. *Project Manager: Neal Balu*

Transient and midterm stability

Large-scale power system disturbances have become of greater concern to both the industry and the public during the last decade. One approach to minimizing the effects of such disturbances is to analyze their causes. Unfortunately, today's system analysis tools are still unable to do this effectively; new and better tools are needed.

The goal of a five-part research project is to develop new analytic tools to facilitate studies of large-scale disturbances (RP1208) based on the currently available transient/midterm stability computer program (RP745). Several new or enhanced features are being implemented in the RP1208 software. Arizona Public Service Co. (APS) is incorporating an improved, two-terminal dc transmission line model, as well as improved machine models and auxiliaries. Arizona State University (ASU) has completed the research efforts involving network reduction and output analysis. Boeing Computer Services, Inc. (BCS), is providing the numerical integration algorithms and program cleanup. Systems Control, Inc. (SCI), in conjunction with Energy Systems Computer Applications, Inc. (ESCA), has developed algorithms for midterm generator aggregations and generator bus reduction. ESCA has extended the aggregation-reduction process to include the external system on a prefault basis. In addition, ESCA is adding the uniform frequency procedure that was developed in *Long-term Power System Dynamics* (EL-367). This option will allow the automatic step-size selection to function better in the midterm simulation region.

The project was started during the first quarter of 1978 and is scheduled to continue through December 1981. With APS's integration and testing complete, BCS is currently working on the final cleanup of the program, and distribution by the Electric Power Software Center is scheduled for March 1982. A workshop on models and algorithms for stability calculations was held in August 1981. *Project Manager: John Lamont*

Software guidelines

The Power System Planning and Operation Program has EPRI-wide responsibility for producing a set of software guidelines as part of a project on software development and maintenance guidelines (RP1714). These guidelines will be followed in future EPRI research projects to obtain better quality, more easily used software for distribution by the Electric Power Software Center. The guidelines will also be available to electric utilities for use in their procurement of software and in their own code development.

The guidelines are organized into 10 chapters that may be used either individually or in various groupings tailored to meet the needs of a particular software project.

Chapter 1 of the guidelines is an overview and briefly describes the remaining chapters and their interrelationships. Chapter 2 provides guidelines for cost estimation and schedule format. The estimation guidelines indicate issues that should be considered in producing a cost estimate. The schedule section describes a milestone, management, and deliverable format for presenting the data. A suggested proposal outline is included.

Chapter 3 is entitled "Quality Assurance (QA) Guidelines." It provides guidance on how the code developer should establish a QA program to detect, analyze, report, and correct software deficiencies. Topics include configuration management, development, maintenance, and diagnostic procedures. Chapter 4 describes the form of all documentation used during the development and maintenance of software codes. It provides general material on style and format of documentation.

The remaining chapters are applicable to the software design, coding, testing, and maintenance phases of the software life cycle. Chapter 5 provides methods for the development of a software specification and for its representation. Design guidelines and the information that should be included in the design are in Chapter 6. Chapter 7 provides coding guidelines that specify language standards (including language choice), as well as coding practices that will increase the reliability, portability, understandability, and testability of software codes. The next chapter contains guidance on the specification, formulation, and documentation of software testing. "Updating and Maintenance Guidelines," Chapter 9, describes procedures for updating and maintenance of the codes being distributed. The final chapter provides specific procedures for the preparation of software for delivery and distribution.

The guidelines provide for the development of as many as nine separate documents from a major software project. The Requirements Specification Document describes the precise requirement for the software. It is the first document produced by the code developer and is the basis for subsequent phases of the project. The Preliminary Design Specification describes the design down to a module (Subroutine and Function) level, while the Detailed Design Specification extends the design to include the logic within modules. Both documents provide a development plan, tests, and a description of the development environment. The Test Plan describes the plan for testing and test analysis after the development and debugging have been completed. The Program Log provides a history of the designs, implementation decisions, tests, and modifications relating to the code throughout its life cycle.

The remaining documents are oriented toward the end user. The Installation Instruction Manual describes the procedures for installing the program on a particular computer. The necessary information to run and use the program is contained in the Users Manual. The Test Results Analysis document describes the tests executed, analysis performed on these tests, and actions taken when tests failed. The Program Reference Manual describes the detailed program structure to a level that permits updating and maintenance of the code. These manuals are intended to complement a well-documented code.

The guidelines should be available in the first quarter of 1982. Science Applications, Inc., was the prime contractor. *Project Manager: John Lamont*

Dispatch operator training

The EPRI hybrid power system simulator was completed in 1975 by the University of Missouri–Columbia (UM–C) to support engineering studies of long-term dynamic behavior of power systems (RP908-1). The capabilities of this hybrid simulator were later extended to include short-term dynamics, protective relaying, and automatic parameter setting (RP908-2). The power system simulation capabilities of the EPRI hybrid are described in *Improvement and Performance Evaluation of an Advanced Hybrid Simulator for Power System Dynamics* (EL-724).

In late 1978 researchers at UM–C began to add the man-machine interface and software to the hybrid so its potential as a training simulator for bulk power system dispatch operators could be evaluated. These operators are responsible for controlling the minute-by-minute flow of power throughout the bulk power system to supply power at the lowest cost possible, while keeping the system secure from serious disturbances. The work to adapt the hybrid and the expected results were described in an earlier *EPRI Journal* (November 1979, page 57).

The adaptions were completed, and the simulator was operational in October 1980. The results have been successful beyond our expectations.

The simulator was demonstrated to an industry group of about 30 supervisory personnel in the fall of 1980. Since then, UM–C has sponsored two 4-day seminars, for groups of 10–15 operators (the first in March 1981 and the second in June 1981). Additional seminars will be held.

This simulator is considered a generic device, somewhat like a driver training simulator (not a Cadillac, just a car). In the same way, this tool is intended to both simulate the basic reactions of electric power and voltage to various system and operator actions, and to train the operator to respond to both normal and emergency situations with knowledge and confidence. It is not intended to simulate a specific power system.

The project has provided a wealth of knowledge in the hardware and software needed to simulate power system phenomena with a fidelity and speed that provide realism to the operator. In addition, the work on scenario simulation—construction of the events to which a trainee will be exposed—will be of considerable value in follow-on work to make simulators increasingly realistic, while reducing their cost. *Project Managers: R. H. Iveson and D. F. Koenig*

ROTATING ELECTRICAL MACHINERY

Transformer oil pumps

The overall objective of RP1797 is to improve the reliability of transformer oil pumps through the application of state-of-the-art and emerging technologies. Pump failure can result in a transformer's being out of service for a considerable time, which can be very costly. (Details of this project were discussed in the October 1980 issue of the *EPRI Journal*, page 45.)

The project is concerned with designing, building, and testing a prototype transformer oil circulating pump or system that will perform the required function but will not cause contamination of the transformer as a result of any failure mode of the pump or pump drive. The new design, or its reasonable modification, should be amenable to retrofit into existing installations.

The project is divided into two phases: The first phase is to generate and evaluate alternative configurations that meet the project objectives. The second is to develop a detailed design for the most promising alternative and to manufacture and test a prototype unit of the selected design.

As a result of the first phase of the project, two improved transformer coolant pump concepts were selected for further study: an improved centrifugal pump and a rotating casing pump. In the second phase of the project, these two concepts were subjected to more detailed study in order to select the best possible design concept. Detailed layouts were prepared, and failure modes and effects were analyzed.

On the basis of these detailed studies, the rotating casing pump concept has been selected for detailed prototype design, manufacture, and testing. *Project Manager: D. K. Sharma*

OVERHEAD TRANSMISSION

Contamination flashover of HVDC insulators

Two important differences exist in the in-service performance of insulators on HVDC lines and their performance on the more familiar HVAC lines: The rate of accumulation of contamination is much higher for dc (about an order of magnitude higher was measured at a field test station). And dc flashovers tend to occur at a lower voltage level than ac flashovers for the same level of contamination (a laboratory study found dc flashover voltage to be only about 50% of the ac rms flashover voltage).

It may be concluded from the findings of a recently completed project by the University of Southern California (USC) that design of HVDC insulation for contamination performance cannot be based on past ac contamination experience and design criteria (RP848-1). However, utility engineers can obtain much practical information on HVDC insulation design from the project's final report, which will be available in late 1981. Following are some of the features of the report.

- Information on the rate and nature of contamination on dc insulators obtained from a field test station, including the effects of weather on the contamination process
- A method for determining the required insulation strength for an HVDC line in any location by knowing the chemical composition of natural contaminants
- Several theories that improve our understanding of the mechanism of dc flashover
- A conceptual design for improving the performance of HVAC insulators by using internal grading

The final report contains not only the basic theory but also the practical applications a utility engineer needs to design insulation systems for HVDC lines. The ultimate goal of this project, other EPRI-sponsored projects (RP1206-1, -2), and a follow-on project at USC (RP1903) is to design insulators for HVDC lines that will have improved operating characteristics and will reduce the cost of line construction and maintenance. The completed project (RP848-1) has identified and quantified the major problems and is a significant first step toward achieving the goal. *Project Manager: John Dunlap*

Transmission line grounding

The transmission line grounding study has passed midpoint and the final report—a grounding design guide for overhead transmission lines—will be available in late 1982 (RP1494-1). This design guide will contain practical information on obtaining ground resistance measurements and analyzing the measurements from a transmission line engineer's point of view. As a part of this project, several dedicated computer programs are being developed by the researcher, Safe Engineering Services, including the following.

- RESIST—a program designed to find the electrical equivalent of the real soil structure at the tower site
- GTOWER—a design tool that will evaluate transmission tower systems and provide information on the effects of mitigation methods for step-and-touch potentials around transmission towers
- PATHS—a computation method for determining fault current distribution between tower and overhead ground wire
- LINPA—a computer code that calculates the self and mutual impedances of the conductors with Carson's method or another approximate, but accurate, method
- TOWER—a program under development that will analyze the lightning performance of a tower

Staged fault tests have been conducted on Idaho Power Co. and TVA transmission lines. Measured fault current distribution between towers and ground wires and earth potential profiles near a faulted tower will be compared with calculated values. Results of current injection tests on Rochester Gas and Electric Corp.'s transmission towers will be used to validate the computer model.

The final report, to be available in late 1982, will contain reference charts and tables for typical designs and, for more complex analyses, the computer programs described above. *Project Manager: John Dunlap*

DISTRIBUTION

Failed-cable analysis

With over one billion feet (0.3×10^9 m) of polyethylene- and cross-linked polyethylene–insulated high-voltage distribution cable presently installed in the United States, there is increasing evidence that the anticipated 30–40-year life expectancy of these cables may not be attained. Excessive failure rates are common at some utilities and have become more common at others. It is possible that additional utilities, in due time, will also experience increased failure rates for cables that have been operating at lower electrical stress, energized for fewer years, and/or subject to less lightning incidence. As a large portion of the installed cables are direct-buried, a potential expenditure of several billion dollars to replace failed cable confronts the utility industry over the next several years. Furthermore, there is additional concern that the replacement cable of the same basic material will also experience premature failure, resulting in a cyclic problem of early-life cable failure and subsequent replacement.

EPRI has sponsored a number of projects designed to facilitate an understanding of cable failure and life predictions (RP133, RP1357); in addition, materials suppliers have been offering cable producers samples of newer, modified polyethylenes and cross-linkable polyethylenes in the interest of enhancing life characteristics. The fact remains, however, that despite years of research (sponsored by others, as well as by EPRI) a question remains as to whether premature cable failure is due primarily to (a) voids, contaminants, and protrusions that exceed industry specifications in specific cable runs (i.e., the older conventional consideration), or (b) a generic problem related to inherent behavior of polyethylene and cross-linked polyethylene when aged in a soil-water environment under conventional voltage stresses (a more recent concern).

To resolve this question, EPRI has entered into a three-year contract with Battelle, Columbus Laboratories, which will employ Institut de Recherche de l'Hydro-Québec as a subcontractor for testing (RP1782). Battelle-Columbus will be responsible for performing a statistical comparison of the histories of 15–35-kV, high molecular weight polyethylene-insulated and cross-linked polyethylene-insulated field-aged cables that have experienced a variety of in-service conditions. A large number of utilities will be participating by providing information; inputs from the cable histories will be computer-processed, and the effects of materials and cable characteristics, operating stresses, local environment, and scores of other parameters will be compared.

The overall objectives will be to develop an understanding of insulation characteristics required for satisfactory service life; to develop an understanding of the relationship between cable operating stresses and cable characteristics; and to recommend preferred insulation characteristics and cable constructions that will increase the reliability of predicting the remaining service life of installed cables. *Project Manager: Bruce Bernstein*

UNDERGROUND TRANSMISSION

Three-conductor gas cable field demonstration

In a cost-sharing effort, The Detroit Edison Co., Westinghouse Electric Corp., and EPRI have cofunded the development and demonstration of an EHV, three-conductor, SF_6-insulated transmission system (RP7840). The specific objectives of this undertaking were to design, manufacture, install, field test, and operate an optimal 362-kV underground link, connected as an integral part of a utility system. This process incorporated an evaluation of technical and economic advantages, operation in a nonlaboratory field environment, and the dissemination of the results to the industry.

To ensure that the technology will be ready and accepted by the industry, the following must be demonstrated.

- Manufacture, shipping, handling, and field installation of components of the size required for a three-conductor transmission system
- Long-term in-service reliability under actual system conditions
- Experience with the operating characteristics and physical limitations
- Industry confidence in the usability of a three-conductor, gas-insulated cable as a viable transmission option

Design optimization, shop tooling, and fabrication of components were completed last year. Installation and acceptance testing of this 183-m (600-ft) test loop at Detroit Edison's Wayne station was recently completed. Figure 1 portrays two stages of the installation process. A two-year test program, including various loading levels and modes, relay carrier tests, and switching surge tests, is under way. This new, three-conductor, gas-insulated link will be connected as an integral part of Detroit Edison's transmission grid for nine months of the test. *Project Manager: John Shimshock*

Morphology of PE and XLPE

Extruded dielectric insulated power cables undoubtedly will be used to meet future demands for increased transmission and distribution because of their low cost and ease of handling. However, field performance of transmission cables is unproven, and distribution cables expected to function for 30–40 years have been failing in a wet soil environment in one-fifth that time, or less. Although the causes of this problem have

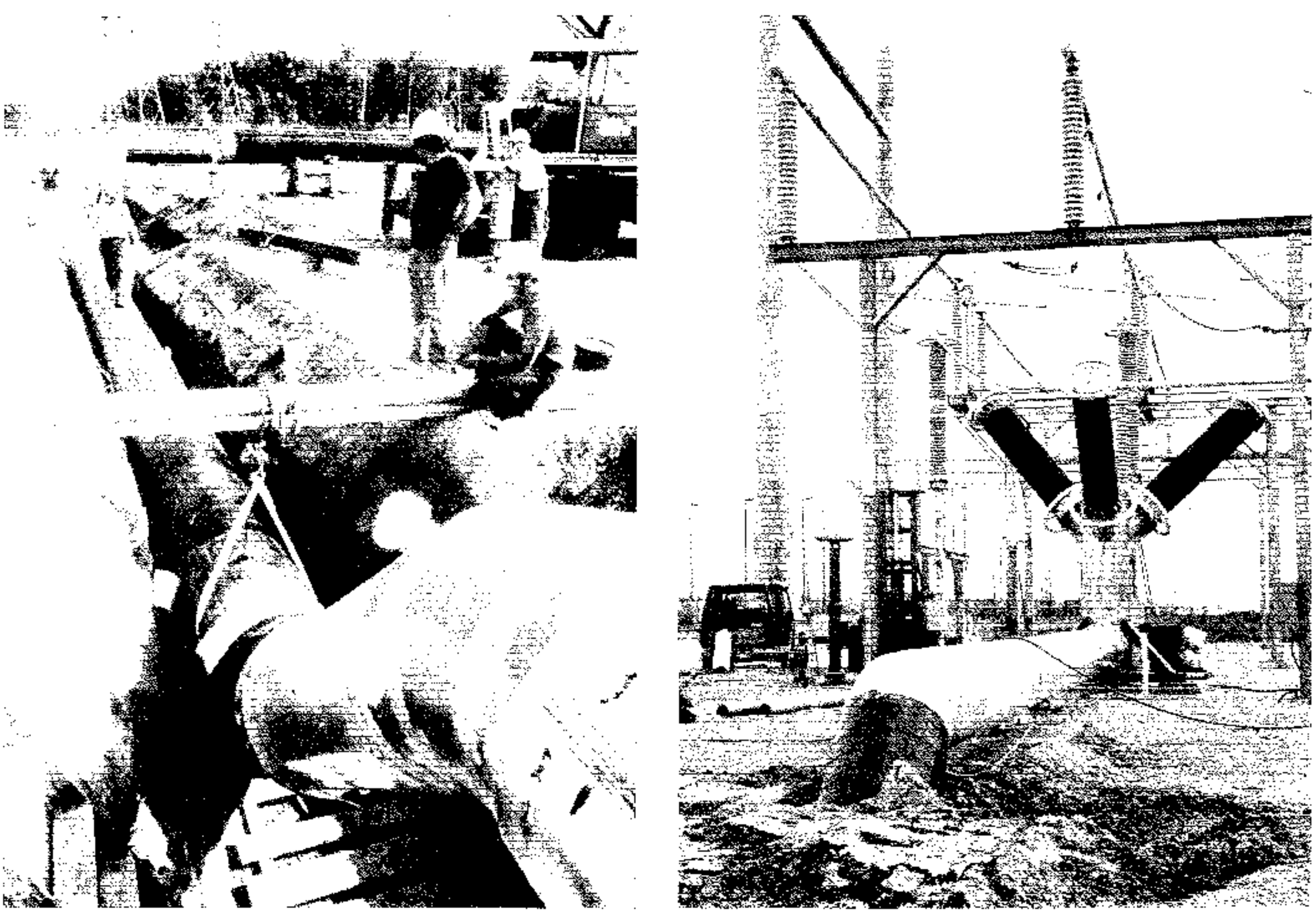


Figure 1 Three-in-one, gas-insulated, 345-kV underground transmission line under construction at Detroit Edison Co. during mid-1981.

remained elusive, technical interest has recently focused on the morphological characteristics (i.e., form and structure) of these materials. Morphological influences represent a relatively unknown factor in this area, and a growing question is whether electrical aging and failure in extruded insulation can be related to such subtle microscopic structural features. Morphology is known to be influenced by processing conditions, as well as by impurities; however, relative to such polymers as high-density polyethylene and polypropylene, less is known about low-density polyethylene, and knowledge about the morphology of cross-linked polyethylene (XLPE) is virtually nil. Reports in the recent literature have claimed that dielectric failure takes place along spherulite boundaries (pom-pom-like structures that polyethylene may form as it cools from the melt), although questions exist concerning experimental methodology.

To gain greater understanding in this area, EPRI has entered into a contract with the University of Utah to explore the morphology of XLPE-insulated transmission cables (RP7891). As a precursor to this project and to explore the state of the art in morphology research on extruded polyethylene cable insulation, EPRI sponsored a workshop that was organized by and held at the National Bureau of Standards. About 30 participants from universities, government, utilities, and industry met for three sessions during March and April of 1981 to present and critique experimental evidence for recently reported structural features in extruded polyethylene. Ten presentations on the subject were given, followed by audience discussion. Etching methods for revealing morphological structures were discussed in depth.

One question raised during the workshop was whether, and to what extent, the objects revealed on the surface of etched specimens are representative of the internal structure of the polymer employed as insulation. Potential problems are that etching techniques may induce degradation, swelling, or other alterations in polymer and, following etching, leave a residue of altered material on the prepared surface. Such altered structures would not represent the bulk of the polymer.

To minimize the potential problem in future work, the workshop reached a consensus on a suggested experimental approach. In this regard, the workshop proved to be quite timely and provided a service not only for researchers concerned with utility problems but also for those involved in academic research. The proceedings of the workshop will be available early in 1982. *Project Manager: Bruce Bernstein*

TRANSMISSION SUBSTATIONS

Hot spot detector

Hot spot detection is an area of high concern to users of transformers, as loss of life is logically expected to proceed more rapidly at such sites. As part of a project with General Electric Co. on transformer loss of life (RP1289-1), EPRI sponsored a subcontract with Luxtron Corp. to evaluate an optical temperature sensing system for use in transformers. The scope of the work involved selecting probe and optical fiber materials; pretesting environmental effects and electrical characteristics; fabricating long-fiber probes and extensions, special feedthroughs, and connectors; and testing in transformers subjected to aging on the project.

The sensor consists of a disk of europium-activated gadolinium oxysulfide phosphor at the end of an optical fiber. The phosphor is excited by ultraviolet radiation transmitted down the fiber from a source within the instrument. The resultant visible fluorescence from the phosphor sensor is transmitted back to the temperature-measuring instrument by the same fiber. The temperature information is contained in the relative intensities of specific fluorescent emissions from the phosphor. The ratioing technique employed makes the temperature measurement insensitive to nonthermal variations in optical signal level.

The phosphor layer is bonded to the tip of an ultraviolet-transmitting silica fiber surrounded by a silicone cladding. The entire probe assembly is protected by a fluoropolymer jacket. All materials in the probe, including phosphor binder and jacket pigment, are electrically compatible with transformer oil and insulation.

One key question that had to be resolved on the project related to whether the optical fiber sensor package would operate successfully in the hostile hot oil environment of the transformer. Another related to whether the properties would remain stable with aging.

Hot oil immersion tests demonstrated satisfactory operation for 2000 hours, the maximum test time, with no change of sensor calibration. Several probes were tested, employing a turn-to-turn transformer coil with an enamel-insulated wire. Typical maximum temperatures at probe locations were in the 124–144°C range. Some deviations were observed between the probes and thermocouples employed in the experiment, but the overall results were satisfactory, and the basic feasibility of the concept was demonstrated. Luxtron will be employing cabled probes in future work to improve physical strength and increase oil resistance. Newly available ultraviolet-transmitting, glass-on-glass fibers may also be evaluated. Longer-term testing in operating transformers is planned. *Project Manager: Bruce Bernstein*

Amorphous metal for transformer cores

The development of amorphous metal transformer cores is an exciting and meaningful venture into a major translation of laboratory art to production technology. Test results reported by the cocontractors, Allied Corp. and Westinghouse (RP1290), are providing considerable optimism that significant savings can be achieved in the distribution of electric energy. The development of amorphous alloy compositions with improved soft magnetic properties for transformer core applications has been a continuing and expanding research effort at Allied since the 1974 discovery of $Fe_{80}B_{20}$, which was designated 2605. During the EPRI project, alloys 2605-S, 2605-SC, and 2605-S2 have shown continuous improvement.

In Morristown, New Jersey, Allied erected a pilot plant that can produce amorphous metal strip; it is, in effect, a small steel mill, capable of processing amorphous alloys in tonnage quantities because it is equipped for the continuous rapid quenching required. The pilot plant has produced 2-in-wide (50.8-mm) metallic glass strip on a semi-continuous basis that typically exhibits 60-Hz core losses of less than 0.1 W/lb at 1.4 T. This energy loss is less than one-quarter of the best grain-oriented silicon steel (M-4). Further, experimental pilot plant casting runs have produced amorphous material with losses one-half of the typical value given above. This is indicative of the potential to further reduce transformer core losses as the technology to produce metallic glasses is developed. Independent tests conducted by Westinghouse have confirmed the outstanding low-loss characteristics of this pilot plant strip.

To date, the pilot plant has produced thousands of pounds of 2-in-wide (50.8-mm) strip in hour-long casts. The strip is continuously wound and the dimensions are measured simultaneously with casting. Although casting runs have been targeted at a one-hour duration, the principle of the system can be readily extended to an essentially continuous process in a fully commercial operation.

The production of the amorphous strip directly from the molten alloy (Figure 2) also achieves energy savings and manufacturing economies by eliminating the numerous intermediate steps of billet casting, hot rolling, pickling, cold rolling, annealing, and coating, which are employed in the manufacture of conventional core steels.

The pilot plant is now producing limited quantities of 6.8-in-wide (172.8-mm) strip at 3000 ft/min (914 m/min). Evaluation tests of this material are under way. The core losses of this wider material are as low as those of the 2-in (50.8-mm) strip made previously. The effort to scale up the production process to produce a wider amorphous metal strip involves a number of major advances in the state of the art of refractory materials, heat transfer techniques, materials handling, and control.

In parallel with production development at Allied, Westinghouse is developing the methods for constructing transformer cores from amorphous strip and evaluating the economic benefits to be realized in commercial designs of distribution and power transformers. The unique physical and mechanical characteristics of amorphous strip present a set of core manufacturing challenges that differ from those encountered with conventional core steels. For example, the high hardness and thin gage increase the difficulty of stamping and stacking the laminations used in large power transformers. Westinghouse is developing methods for laminating individual strips into thicker bonded sheets to partially overcome the problems of stacked core construction. New high-speed machinery capable of forming and stacking multiple laminations may be needed to produce stacked cores in a cost-effective manner. This provides an excellent opportunity for using the emerging robotics technology. The high tensile strength of the material may even facilitate more economic production of wound core distribution transformers by using automated, high-speed winding equipment.

Figure 2 Transfer of molten metal from induction melting equipment into casting machinery during the manufacture of 6.8-in-wide (172.8-mm) Metglas amorphous transformer core strip in the EPRI–Allied Corp. pilot plant.

Westinghouse is also studying the stress sensitivity of amorphous metal so that cores can be assembled with a minimal increase in losses from stress imposed by various geometric shapes. Another characteristic of this material is its high resistivity, which at certain widths requires no coating, thereby eliminating one step in its manufacture.

The Westinghouse portion of this project includes extensive core design and loss-evaluation studies. Two characteristics that affect these areas are the space factor and saturation induction. The space factor represents the fraction of total core volume that is filled with core material. Amorphous strip as currently produced has a space factor between 80% and 85%, compared with 95% or greater for conventional silicon steels. The lower space factor of amorphous strip results from its thinner gage and surface imperfections.

The economic advantage of amorphous strip is decreased by the lower space factor because larger core volumes are required to obtain the same flux. This increases the amount of conductor required for the coil and therefore the load losses of the transformer. Improved strip-casting methods with higher space factors are being developed at Allied.

The inherent lower saturation induction level of amorphous strip compared with silicon steels is due to the percentage of glass-forming materials needed in the alloy to produce an amorphous material. This lower saturation level, originally thought to be the major stumbling block in its application, is not now considered a significant factor. This is because of the nation's dramatic increase in energy and capital costs, which has forced designers to reduce the saturation induction of silicon iron below the maximum operating induction of amorphous metal simply to reduce core loss. Ironically, we anticipate that an amorphous metal transformer will actually weigh less than a silicon iron transformer when both are designed with present-day loss evaluations. *Project Manager: Edward Norton*

R&D Status Report
ENERGY ANALYSIS AND ENVIRONMENT DIVISION

René Malès, Director

SOCIOECONOMIC IMPACTS OF POWER PLANTS

The introduction of a new power plant into a region can have positive and negative socioeconomic impacts on the region. Positive effects include increased tax revenues and increased local employment. Negative impacts generally result from the influx of a large temporary construction force, which can strain local services, upset traditional markets for housing and other services, and create conflicts between older residents and newcomers. Concern about the negative impacts has forced utilities to address these issues. The work described below attempts to improve our understanding of plant impacts and to evaluate methods for predicting them.

Before the 1970s little attention was paid to the socioeconomic impacts of new power plants. The National Environmental Policy Act of 1969 was the first federal legislation requiring consideration of these impacts. Other federal requirements have followed, including the Nuclear Regulatory Commission's (NRC) Regulatory Guide 3.8 (Chapter 8) and the Council on Environmental Quality's guidelines for environmental impact statements. Also, in several states industrial siting legislation has been created or expanded to require more comprehensive coverage of socioeconomic impact assessment and mitigation.

EPRI has sponsored a two-year research project to address these socioeconomic issues (RP1226). To supplement existing data, detailed information was collected from 12 power plants either under construction or recently completed. These case studies were chosen to reflect diversity in geographic location and in economic development. About half of the plants are in areas of low population density. Nine burn coal, two are nuclear, and one is oil-fired. They range in size from 504 to 2664 MW (e).

The project had four objectives. The first was to provide an expanded data base on socioeconomic impacts, both positive and negative, resulting from power plant construction. This data base will support general conclusions about the occurrence and magnitude of socioeconomic impacts and will provide a set of reference precedents for use in preparing impact assessments. The second objective was to evaluate the state of the art in socioeconomic impact assessment in order to identify the more useful tools and suggest approaches for future assessments.

The third objective was to explore the sensitivity of potential adverse impacts to changes in other variables, such as the type and quantity of housing and services available for construction workers. This work could suggest options for utilities, construction contractors, and governments that might mitigate adverse impacts. The fourth objective was to develop early-warning methodologies for identifying circumstances that might cause either serious or minimal adverse socioeconomic impacts. Such methodologies could be helpful in determining whether further socioeconomic assessment work is warranted.

The project contractor was the Denver Research Institute, which was assisted by the firm of Browne, Bortz, and Coddington. The project greatly benefited from the activities of an advisory committee composed of representatives from utilities, national laboratories, universities, private consulting firms, and NRC. This group closely oversaw the work and participated in many key decisions.

The project has been completed, and the final report will be available by the end of the year. The following types of impacts were investigated.

- Direct economic: direct employment (construction and permanent), local versus nonlocal hiring, local versus nonlocal expenditures
- Indirect economic: changes in local service employment and in labor supply and demand
- Demographic: changes in population, settlement patterns, and such characteristics as family size, income levels, and labor participation rates
- Housing: changes in effective demand and in supply constraints
- Public sector: changes in facility and service requirements, local government tax base and revenues, government operating costs and capital improvement needs, and government functions
- Private sector: changes in per capita availability of goods and services, responses of local businesses

The study has produced these major conclusions: (1) because impact forecasts are generally unreliable, versatile management schemes for construction projects may be desirable; (2) the changing craft structure of the construction work force influences socioeconomic effects; (3) the geographic area affected is considerable; (4) indirect or secondary economic impacts are generally small, and fiscal impacts vary considerably; (5) the demand for permanent housing among migrating construction workers is small; and (6) most public officials see the overall plant impacts as positive.

Impacts are generally related to the number of construction workers at a plant site. At the case study sites and other recently built plants, the actual timing and magnitude of construction employment differed substantially from the forecasted estimates. In most cases, there were also delays in completing construction. The magnitude of construction employment (both peak and total man-years) usually exceeded the initial projections by a wide margin.

There were many reasons for the poor estimates, including several factors beyond the utilities' control—for example, regulatory action or inaction, availability of financing, material shortages, load forecast changes, and labor stoppages. Such factors lead to considerable uncertainty in forecasting construction schedules. Given this uncertainty, there is probably a need in future impact assessments to prepare multiple scenarios for project startup and completion as well as for the size of the construction work force. This approach would allow a much greater understanding of the potential impacts and facilitate the design of versatile management schemes to deal with the various possibilities.

The case studies demonstrate the importance of understanding the dynamics of the construction work force in assessing socioeconomic impacts. Typical plant construction initially involves large numbers of laborers, carpenters, concrete workers, and sometimes operating engineers. As the project progresses, there is a shift toward more ironworkers, pipe fitters, boilermakers, and electricians. Individual workers are not likely to be employed at the plant over the entire construction period and are employed for shorter periods than usually predicted. This results in significantly less demand for permanent housing in the immediate vicinity of the power plant than typically forecast.

In nearly all of the case studies, the geographic extent of the impact area was greater than had been forecast. Workers tended to commute on a daily or weekly basis from a much larger area than anticipated. This was partially due to the existence of moderately large indigenous construction work forces, even in some of the rural areas. Many of these areas have undergone fairly continuous (albeit unremarkable) development, which has attracted a resident labor force available to work on power plant construction; hence the need to import new workers was smaller than expected.

The case studies indicate that construction workers usually have minor secondary impacts on the economy of an area. Most forecasts have tended to overestimate these impacts.

Surveys of the housing preferences of migrating construction workers have found that they prefer permanent housing. The case studies, however, indicate that the predominant types of housing for such workers are mobile homes, recreational vehicles, and long-term rentals (including motels and boardinghouses as well as apartments and houses). There was no evidence that construction workers attracted into an area because of a power plant have a significant impact on the local new housing market as buyers of single-family homes. The changing mix of construction crafts, the shorter-than-projected time on the job, and the high costs of permanent housing in most areas had much to do with the type of housing typically chosen by construction workers.

The fiscal impacts of a power plant on a local area vary tremendously, depending on plant ownership and state and local laws. Some public agency–operated plants make no payments to local areas, but most plants either pay local property taxes or make payments in lieu of taxes. Jurisdictional mismatches due to local laws and/or boundaries—that is, cases in which the governments receiving the revenues from the new plant are not those affected—can create problems. In general, however, the case studies demonstrate that the construction of a power plant in an area can have a positive effect on community standards for public services and facilities. Many new public facilities have been constructed in the case study areas as a result of additional funds due to the project. The governments involved have placed less emphasis on upgrading services than on providing new facilities.

Those interviewed in the case study areas (primarily public officials, community leaders, and other influential citizens) tended to consider the overall impacts of power plant construction and operation to be positive. The positive impacts most frequently cited were increased employment (especially for the young), increased retail sales, increased property tax revenues, and increased optimism in the business and service sectors. The negative impacts cited, such as high rents for housing, were usually viewed as temporary annoyances that had to be borne (possibly by others than those interviewed) in order to reap the positive benefits. Most were associated with the peak construction period.

The characteristics of the area in which a plant is located greatly influence the nature and extent of its socioeconomic impacts. For the three case study plants near metropolitan areas, neither positive nor negative impacts were perceived as significant. Economic impacts from power plant construction and operation represented a very small percentage of total economic activity in these cases. This suggests that when power plants are built in this type of setting, socioeconomic impacts are likely to be of small consequence. At the other extreme—plants sited in very rural areas remote from even small and medium-size cities—socioeconomic impacts can be very important, and more detailed analyses may be warranted. *Program Manager: Ronald E. Wyzga*

RATE DESIGN STUDY: COSTING FOR RATEMAKING

The Electric Utility Rate Design Study, now in its sixth year of load management research, has published more than 80 reports on various technical aspects of assessing time-of-use rates and direct load controls. Undertaken in response to a request by the National Association of Regulatory Utility Commissioners to examine ways of controlling peak demand growth and shifting use from peak to off-peak periods, the study is a nationwide research effort sponsored by EPRI, the Edison Electric Institute, the American Public Power Association, and the National Rural Electric Cooperative Association. The study's second phase (1978–1981) was organized into six major topics: customer response (or elasticity), costing and rate design, load research, equipment for load management, customer acceptance and understanding, and cost-benefit analysis. Research has been summarized in a topic paper for each area. This report discusses completed work on costing for ratemaking, which is covered in Topic Paper 2 (RDS No. 85), the last topic paper to be published. A final report (RDS No. 90) will soon be issued that summarizes the study's second phase and provides a perspective for interpreting the results.

During the 1970s rate design emerged as a prominent concern because it was perceived as one solution to the problem of increasing utility costs and electricity rates. One portion of the Rate Design Study analyzed the feasibility of time-of-use rates and direct load controls as ways of holding down increases in the costs of providing electric service. As part of this research, the study explored the development of appropriate methods for (1) determining costs and how they vary over time, and (2) signaling to customers (through rates that reflect costs) that peak period electricity use is more expensive than off-peak use.

The subject of costing is a central issue of the Rate Design Study. The application of costing to ratemaking has been at the core of the debate about whether load management should be implemented by electric utilities and if so, how. Moreover, costing methods have been an important tool in meeting such ratemaking objectives as fair resource allocation, revenue adequacy for the utility, rate stability, and understandability of rate forms.

Rates can be cost-based and still deviate from costs. Possible reasons for such deviations include rate simplicity, consumer bill impact, historical practices, legislative fiat, and conservation. Topic Paper 2 clearly demonstrates that there is no single "right" costing method. All involve underlying assumptions about how real-world costs should be mirrored in calculations. However, this does not mean that costing methods cannot be derived and applied to ratemaking questions. Rather, it emphasizes the need for a clear enumeration and ranking of pricing objectives in order to derive costing methods (or mixes of costing methods) that best meet those objectives.

Costing methods

The major research effort of the study was to develop methods for calculating costs. Sixteen cost studies were performed by three consultants for eight utilities. In all cases, costs were found to vary by time of use. Thus the study focused on developing costing methodologies that could serve as the basis for time-differentiated rates. The two major types developed were time-differentiated accounting cost (TDAC) methodologies and time-differentiated marginal cost (TDMC) methodologies.

Accounting costs are the costs recorded on the financial books of a company. They represent the incurred costs of the utility. TDAC methodologies are similar in concept to traditional cost-of-service studies, which categorize accounting costs in three steps: functionalization (i.e., generation, transmission, distribution); classification (demand, energy, customer); and allocation to customer classes (residential, commercial, industrial). TDAC methodologies add another step, the allocation of joint costs (i.e., demand- or kW-related costs) to peak and off-peak time periods. These periods may be hourly, weekly, monthly, or seasonal.

Topic Paper 2 presents four methods of computing TDAC, which were developed by Ebasco Services, Inc.; Charles T. Main; Putnam, Hayes & Bartlett, Inc.; and Ernst & Whinney. Multiple methods were developed because there are multiple ways to allocate costs; no one method satisfies all the pricing objectives. The report suggests these criteria for choosing between alternative TDAC methods: consistency with pricing objectives, conceptual validity, and ease of implementation.

The four TDAC methods, which are compared in Table 1, have similar general approaches. Differences between them are focused on the most important step, the allocation of joint costs to time periods. A comparison of the peak and off-peak period cost allocations under the four methods indicates that results can vary significantly from method to method. For example, the Putnam, Hayes & Bartlett method tends to allocate a much greater proportion of joint costs to the peak period than the other methods, resulting in higher on-peak demand costs and higher ratios of peak to off-peak costs.

While the TDAC methods differ significantly in allocating joint costs to time periods, their approaches to allocating energy costs are identical. Each method assigns the average running costs obtained from a system dispatch model to the time periods in which these costs occur.

Topic Paper 2 concludes that all TDAC methods entail judgments on the part of the user that significantly affect the resulting cost burdens and rate structure. Nevertheless, these methods have achieved wide acceptance as fair ways of sharing the auditable costs of the utility.

Marginal costs represent another primary measure of a utility's costs. Conceptually, the definition of marginal cost is simple: it is the cost of producing one more unit of goods or the savings from producing one less unit. In practice, the term is more ambiguous because there are short-run marginal costs (when existing capacity is fixed) and long-run marginal costs (when all capacity is variable). Marginal costs are forward-looking and as such are projected rather than incurred costs. Uncertainty about the future can affect the ranges of marginal cost estimates. Yet it is this incremental, forward-looking nature of marginal costs that is the basis for the claim that they are economically efficient and socially equitable. The price the customer should face when deciding whether to consume one more unit should be the cost of producing that additional unit.

Four TDMC methods were investigated during the study. Other methods exist, but these four are representative of the various approaches and are relatively well documented. The developers are Cicchetti, Gillen, and Smolensky; Ernst & Whinney;

Table 1
TIME-DIFFERENTIATED ACCOUNTING COST METHODS

	Ebasco	Ernst & Whinney	Main	Putnam, Hayes & Bartlett
Steps included				
Functionalization	Yes	No	No	No
Classification	Yes	No	No	No
Allocation to costing periods	Yes	Yes	Yes	Yes
Allocation to customer classes	Yes	No	No	Yes
Cost functions included				
Generation	Yes	Yes	Yes	Yes
Transmission	Yes	No	No	Yes
Distribution	Yes	No	No	Yes
Type of data emphasized for allocating joint costs to costing periods	Supply	Supply	Supply	Demand

Table 2
TIME-DIFFERENTIATED MARGINAL COST METHODS

	Cicchetti, Gillen, and Smolensky	Ernst & Whinney	Gordian Associates	National Economic Research Associates
Calculation of generation capacity costs	Cost of moving next plant ahead a year in the construction schedule, net of fuel savings from displacing less efficient plants in dispatch	Production functions estimated for each generation technology	Shadow price from linear programming model	Annualized capital cost of unit used to meet an increase in system peak
Calculation of generation energy costs	System lambda	Capacity and energy costs usually combined	System lambda	System lambda
Generation mix used in marginal cost calculations	Existing plant, plus utility's planned capacity expansion plan	Plant configuration assumed to be instantaneously reoptimized	Existing plant, plus optimal capacity expansion plan	Existing plant, plus peaking unit
Costing horizon	Short run	Long run	Short run	Short run
Allocation of costs to time periods	LOLP* to allocate to peak periods and then equally among all kWh in peak periods	Relative magnitude of demand to allocate to periods and then equally among all kWh in peak periods	Hourly LOLP and then aggregate to periods	Hourly LOLP and then aggregate to periods

*Loss-of load probability (a measure of the probability that any period may become a peak period).

Gordian Associates, Inc.; and National Economic Research Associates, Inc. As in the case of TDAC methods, multiple TDMC methods were investigated because each has a unique way of attributing costs and defining a marginal generation unit for purposes of determining the incremental costs of system expansion. Again, the criteria for choosing among the methods are consistency with pricing objectives, conceptual validity, and ease of implementation.

The four methods differ significantly in their estimation of marginal generation costs, while the procedures for analyzing transmission and distribution costs are quite similar. Table 2 compares the methods in terms of the generation cost calculation and three other significant factors: whether costs are based on the utility's present system or on an ideal system, whether short- or long-run marginal costs are calculated, and how capacity costs are assigned to time periods.

Topic Paper 2 concludes that both TDAC and TDMC methods require the user to make judgments. However, these judgments differ in nature. TDAC analysts must determine equitable means of allocating accounting costs to periods and classes. TDMC analysts must make decisions about how best to measure the cost of an additional kilowatt or kilowatthour at different times of the day and year and to attribute the cost to the customer class exhibiting incremental demand.

Costing periods

The concept of costing periods is critical in time-differentiated cost methodologies. A costing period is a period in which the cost of providing electricity is nearly the same for each hour. Hourly costs can be used to determine these periods, but calculating hourly costs is time-consuming and this level of detail is often not needed. An alternative is to calculate costs for the period as a whole. With this approach, however, one is quickly caught up in a chicken-or-egg-type problem: costs by period are needed to determine costing periods, and costing periods must be specified before costs by period can be calculated.

To solve the dilemma, substitute measures for costs can be used to initially identify costing periods. Then joint costs can be allocated to periods, and the original periods can be modified on the basis of cost variations between and within periods. Valid costing periods are those for which the cost variation within periods is smaller than the variation between periods.

Topic Paper 2 reviews seven approaches to costing period identification. These were developed by Ebasco; National Economic Research Associates; Ontario Hydro; Long Island Lighting Co.; Putnam, Hayes & Bartlett; Charles T. Main; and Ernst & Whinney. The methods vary in the measures used to substitute for costs and the analytic processes used for period identification. Substitute measures for costs may be categorized as demand-related, supply-related, or both. One demand-related substitute is hourly load data. Supply-related substitutes usually rely on generating unit operating characteristics. Most costing period identification procedures use both demand- and supply-related data, emphasizing one or the other.

The topic paper concludes that selecting between the various costing period identification methods is a matter of judgment. There is no theoretical basis for declaring one procedure better than another. The choices made can have considerable effect on one of the most important considerations of time-differentiated rates, the ratio of peak to off-peak costs. Broad periods tend to smooth out dramatic differences between periods; narrow periods tend to accentuate differences and thereby cause large peak to off-peak differentials. Selecting one method over another, or applying a method in a unique way, can have dramatic effects on period lengths and thus on peak to off-peak differentials.

Ratemaking

Findings that the costs of supplying electricity vary significantly by time of use, together with the desire of utility executives and regulators to hold down rate increases, led to the attempt to develop methods to derive rates that accurately reflect costs. The research focused on time-differentiated rates, principally time-of-day rates. However, seasonal, interruptible, and load control rates were also investigated. Other rate forms were examined, including penalty prices, non-time-differentiated block rates, and lifeline rates.

Time-differentiated rates satisfy many commonly held pricing objectives. In fact, some of the objectives enumerated by the economist James Bonbright in 1961 and by the Public Utility Regulatory Policies Act of 1978 are better met by time-differentiated rates than by non-time-differentiated rates. For example, when time-differentiated rates reflect the utility's costs better than non-time-differentiated rates, time-differentiated rates may be viewed as more equitable. In many cases, innovative rate structures may improve the utility's ability to recover its costs as load patterns change. Finally, time-differentiated rates may result in more efficient use of the utility's facilities and resources as well as society's resources.

The Rate Design Study focused more on the determination of appropriate costs (marginal versus accounting) than on the development of procedures for implementing time-differentiated rates. Nonetheless, some useful findings on ratemaking procedures and issues are reported in Topic Paper 2. Discussions on rate forms, rate components, revenue reconciliation procedures, and class revenue requirements are included in the chapter on ratemaking.

Transfer activities

Given the large number of new concepts and methodologies developed during the Rate Design Study, it was decided that considerable effort should be devoted to transferring the research findings on costing for ratemaking to the industry.

Regional workshops were held at which over 400 staff members from utilities and state public service commissions calculated time-differentiated marginal and accounting costs and used these costs to develop time-of-use rates. Emphasis was placed on the functional steps that need to be performed in the costing and ratemaking process and how the various methods' calculations compare at each step.

Differences between methods were highlighted by applying each method to a common data base. Comparisons of the results showed that selection between alternative methods depended more on particular utility circumstances and assumptions about the future than on the "correctness" of any given method. Each technique can be applied under many different utility operating circumstances but will yield different results in each case. Pricing objectives guide the selection process. Much of the workshop program dealt with helping decision makers determine whether various techniques are appropriate to their situations and which techniques best meet their particular pricing objectives.

The workbook used at the workshops is available as a two-volume Rate Design Study report (RDS Nos. 93A and 93B). *Project Manager: Nancy Hassig*

R&D Status Report
ENERGY MANAGEMENT AND UTILIZATION DIVISION

Fritz Kalhammer, Director

ALTERNATIVE TECHNOLOGIES FOR DUAL ENERGY USE SYSTEMS

Dual energy use systems (DEUS), which involve the simultaneous production of electricity and useful thermal energy, are being reexamined by industry and the utilities as a means of extending fuel supplies and expanding generation capacity. In September 1977 EPRI conducted a workshop to develop information useful to utilities, process industries, and others concerned with the problems and prospects of DEUS. The workshop found that although much had been written about various applications, such as cogeneration and district heating, not enough information was available on present and future uses to make an accurate estimate of DEUS potential. Thus EPRI initiated a project to evaluate alternative DEUS technologies and identify attractive applications (RP1276).

The major objectives of RP1276 are to develop a methodology for assessing DEUS options, giving explicit consideration to utility perspectives; to identify promising combinations of prime movers and industrial processes with uses for their thermal energy output; and to identify R&D needs and priorities. In order to develop an understanding of the technical, economic, and institutional factors affecting DEUS success, surveys of existing industrial cogeneration and district heating systems were undertaken. These surveys have been completed, and system analysis and conceptual design development efforts are now under way.

Industrial cogeneration

Cogeneration provided a significant fraction of U.S. electricity during the early decades of this century, but currently it represents only about 4% of the nation's generation. Since 1973, increases in petroleum prices have renewed interest in cogeneration. By offering qualified cogenerators several incentives, the Public Utility Regulatory Policies Act of 1978 (PURPA) and subsequent regulatory rulings have further increased interest in cogeneration. How much new cogeneration capacity will be added to the grid is highly dependent on continued economic attractiveness and regulatory support.

Parallel to the passage of PURPA, DOE undertook two major cogeneration efforts—one to evaluate advanced generation options and their potential for cogeneration in various industries and another to examine the retrofitting of five energy-intensive industries with cogeneration. However, neither DOE study addressed the impact of cogeneration on the utility system, which is a major focus of EPRI's cogeneration effort under RP1276.

The first step in EPRI's effort was the industrial cogeneration survey, in which detailed information on 17 operating systems was collected. The factors addressed included types of cogeneration systems and components, relative thermal and electric output, capital investments, operation and maintenance costs, arrangements for ownership and operation, and interactions with utilities. The study also sought to identify utility attitudes toward industrial cogeneration. In an ongoing activity, a list of industrial cogenerators is being maintained. Initially, some 250 cogenerators with almost 7800 MW of installed capacity were identified. This list has recently been updated and now includes over 400 cogenerators with approximately 14,000 MW of installed capacity, which represents about 3% of existing U.S. cogeneration capacity. The results of the industrial cogeneration survey are presented in EM-1531, prepared by Synergic Resources Corp.

The survey has provided an information base for the next tasks in the industrial cogeneration effort—systems analysis and conceptual design development. The objective of this work is to develop conceptual designs and utility impact assessments for specific cogeneration applications. It entails identifying suitable candidate industries, defining system requirements, and assessing alternative system designs. To date, two important industries have been selected for conceptual design development—pulp and paper and enhanced oil recovery. Industrial-scale applications of distillation are currently under consideration, and a fourth generic candidate remains to be selected.

A computer program has been developed by General Electric Co. as a screening tool for the evaluation of cogeneration plants. It can determine performance, costs, and benefits in matching cogeneration systems to industrial applications and the requirements of the local utility. Included in the program's data base are data on the sizing, cost, and off-design characteristics of the following: noncogeneration boiler; pulverized-coal-fired boiler with flue gas treatment and intermediate-pressure steam turbine; atmospheric fluidized-bed boiler with intermediate-pressure steam turbine; gas turbine with heat recovery steam generation (HRSG); gas turbine with HRSG and steam turbine (combined cycle); integrated coal gasification–combined cycle (oxygen blown); phosphoric acid fuel cell with supplementary-fired HRSG; and diesel engine with HRSG and open-cycle heat pump.

Also covered by the data base are the properties and availability of seven different fuels; industrial process data as a function of fluctuations in utility rates or variable operation and maintenance; and the electrical, fuel, and thermal requirements of the process. The program is being exercised by several contractors, and the results are being compared with those from conventional methods of selecting and sizing cogeneration equipment. General Electric is now documenting the program and refining its output. Also, the data base is being expanded to accommodate the off-design characteristics of additional equipment.

The first conceptual design effort undertaken was for the pulp and paper industry. The goal was to develop optimal cogeneration facilities for two sites in different parts of the United States. Energy use at each pulp mill was metered under various operating conditions, log sheets and other mill records were examined, and mill personnel were interviewed in order to determine energy requirements for each area in each mill. Recent developments in pulping technology were assessed to determine process configurations for a new mill for each site (to be completed in 1985). Flow diagrams and site plans were developed. The plant design was submitted to a panel of pulp and paper industry representatives and equipment manufacturers for review and was modified on the basis of their comments.

Eight different cogeneration configurations are being considered for the modified plant design at each site. The General Electric computer program is being used to check selection and sizing of the least-cost configuration. The conceptual design should be completed this month.

A similar conceptual design effort is under way for the use of cogeneration in enhanced oil recovery, which has substantial potential for cogeneration capacity in several parts of the United States. Two sites have been selected. At the first, in south central Texas, EPRI is working with Conoco and Central Power and Light Co. The petroleum resource at this site is tar sands. The steam requirement is 1.6×10^6 lb/h, and the electrical requirement (principally for pumping) is 30–50 MW. Other oil companies have properties in the same area. If these fields are developed by using coal, lignite, or petroleum coke in atmospheric fluidized-bed boilers or with a gasifier, they might be able to provide several hundred megawatts of cogeneration capacity. The other site, owned by The Oil Shale Co. (Tosco), is in Southern California Edison Co.'s service territory. The steam requirement at that site is 100,000 lb/h, and the fuels available for use are natural gas and petroleum coke. The prospects for development of both sites with the cogeneration options identified in this project appear good. The conceptual design work is due for completion in the summer of 1982.

In addition to the development of conceptual designs for other generic industries, future efforts will address the impact of multiple cogeneration systems on utility resource plans and economics; the advantages offered by advanced technologies (e.g., fuel cells) when used as DEUS prime movers; situations in which utility cogenerators supply thermal energy to a number of industries in an industrial complex; and DEUS R&D needs.

District heating

DEUS district heating systems have received increased interest since the 1973 oil embargo because of their energy efficiency and their widespread acceptance in Europe. A district heating survey was conducted for EPRI by EUS, Inc., and Hittman Associates, Inc. This effort included a review of literature on district heating activities in the United States and on current practices in five European countries. Also, a survey of U.S. electric utilities that operate district heating systems was conducted. Of 59 total, 48 provided detailed operating and economic information. Brief case histories of 10 of these systems are included in the project report (EM-1436).

The utility survey, the literature review, and interviews with utility executives produced these major findings.

- U.S. steam district heating systems have higher costs than European hot water systems.
- From a utility standpoint, the manpower and cost required to manage district heating systems are large in relation to the return on investment or in comparison with a similar effort in the electric power operation.
- The high cost of installing distribution systems is considered the largest economic impediment to building or revitalizing district heating systems.
- Although hot water systems appear technologically superior to steam systems, European experience and economics are not directly applicable to the United States because of differences in environmental regulations, subsidies, customer hookup requirements, and the greater European dependence on high-cost oil for heating.

On the basis of these findings, it was decided that the next objective of the district heating effort should be to identify the most favorable U.S. sites for district heating with hot water technology. Taking advantage of the European experience, a preliminary feasibility analysis of the application of hot water technology in the United States has been initiated. In the first phase of this contract, Burns and Roe, Inc., has assessed transmission and distribution networks, district heating turbines, user heat transfer equipment, and thermal storage.

In the current phase, 19 criteria are being used to screen potential sites for hot water systems. Conceptual designs will be developed for the sites found to be most attractive. Both existing and advanced technologies will be assessed. An extensive analysis of European district heating equipment, installation strategies, and problems is under way and will be used in developing the site-specific conceptual designs. This effort is scheduled to be completed by the end of 1982. *Project Managers: Robert Mauro and David Hu*

R&D Status Report
NUCLEAR POWER DIVISION

John J. Taylor, Director

REVIEW OF RECENT LARGE LMFBR DESIGNS

In the period 1975–1979 EPRI sponsored competing conceptual designs for a 1000-MW (e) liquid metal–cooled breeder reactor plant. Three concepts for loop-type plants were jointly sponsored with ERDA (now DOE), followed by three pool-type plant studies sponsored by EPRI alone. Each of the concepts was prepared by a team consisting of a reactor system vendor and an architect-engineer. The diversity among the six concepts, all prepared in response to the same design requirements, led to reviews to examine their relative merits, their strong points, and their shortcomings. The first group of reviews to be completed assessed the maintainability, inspectability, and operability provided in the various concepts (RP1704).

Maintainability

A team of persons who had been directly responsible for maintenance on the EBR-II and Enrico Fermi-1 LMFBR plants, selected for this assignment by ETA Engineering, Inc., performed the assessment of these designs for maintainability (NP-1714, 2 vols.). Rather than an exhaustive review of all potential maintenance requirements for total plant concepts, the methodology of this review consisted of evaluations of a few significant maintenance cases that could affect plant availability.

The following specific cases were examined for outage time, safety, personnel exposure to radiation, and general practicality of the proposed maintenance methods.

- Replacement of an intermediate heat exchanger in each of the three loop-type and three pool-type concepts
- Replacement of the upper internal structure in one of the pool-type concepts
- Replacement and repair of a primary pump in one of the pool-type concepts
- Replacement of a spent cold trap in two cases—an in-reactor plug-in unit and an out-of-reactor unit
- Repair operations on a CRD driveline performed in the sodium components maintenance facility proposed for one of the pool-type concepts

The three design teams provided concepts that differed substantially in the facilitation of major maintenance operations. One reason for the disparate maintenance provisions appears to be a tendency to exclude from consideration those operations that are judged unlikely to be required; such judgments were challenged by the reviewers. An example of variation in maintainability is the variation in time required to replace an intermediate heat exchanger—from two months for one of the pool-type concepts to up to a year for a welded-in intermediate heat exchanger in the loop-type concepts. (It was recommended that loop-type concepts adopt the removable tube bundle to overcome this maintainability problem.)

The most fundamental finding of the maintainability review is that an acceptable degree of maintainability can be achieved in a new plant concept only through the responsible participation of experienced maintenance engineers in the earliest definition of the concept.

Inspectability

The review of the six design concepts for inspectability was performed by Rockwell International's team of sodium technology test facility engineers who were not involved in any of the designs under review. Again, the methodology of the review was to assess the inspectability of a few cases that could characterize a concept, rather than to review the total plant designs (NP-2021). The following cases were studied.

- One loop of the primary heat transport system of a loop-type plant
- Structural systems supporting the reactor tank and its guard tank in a pool-type plant concept
- Tank wall surfaces of a pool-type reactor tank and guard tank
- Emergency decay heat removal system—direct, in-reactor type
- Pool-type reactor deck structure and tank wall bimetallic weld

The inspection requirements on which the review was based were the rules for in-service inspection of the ASME Boiler and Pressure Vessel Code (specifically, the September 1979 draft of the rules for LMFBR plants). These rules specified requirements for the minimum periodic examinations, contingency examinations in cases where faults were found, and postrepair examinations to verify acceptability of repairs. In addition, the general design requirement proposed by EPRI that "uninspectable was unacceptable" was also taken as a guideline.

The case of inspection of one loop of the primary heat transport system of one of the loop-type concepts proved by far to be the most significant of the cases reviewed because it included not only the primary piping but also one primary sodium pump and one intermediate heat exchanger. Because this case is very dependent on the radiation field existing at these components and because of substantial discrepancies found in the design documents, the reviewers included an extensive and carefully referenced reestimate. The fields existing in the primary loop were found to be between 200 and 2200 mrem/h. There were places requiring inspection at each point of support of the sodium piping. The estimated requirements for inspection of the various cases examined are given in Table 1.

Table 1
INSPECTION REQUIREMENTS
(per 10-yr interval)

Case	Man-hour	Man-rem	Inspection Equipment ($)
Primary loop			
one	22,000	580	800,000
all four	74,000	1730*	800,000
Reactor support structure	9600	15	875,000
Guard tank support	200	0	200,000
Reactor and guard tank surfaces	2500	0	150,000
Emergency decay heat system	50	0	0
Pool reactor deck	18,000	47	400,000
Pool bimetallic weld	2000	5	600,000

*Based on annual inspection of progressive fractions, annual inspection crew is between 260 and 550 persons, of whom between 210 and 425 receive 80% of allowable burnup.

Operability

General Physics Corp. performed the review for operability of the design concepts. One of the loop-type plant concepts and one of the pool-type were used as reference concepts, and the other four designs were studied when there were significant differences from the references. GPC personnel were familiar with the operation of commercial nuclear plants and had Fast Flux Test Facility experience. The team was assisted by a consultant who had extensive experience at Fermi-1. Extensive consultations with EBR-II and FFTF operating personnel further augmented the operability review.

Specific operating modes and off-normal conditions (Table 2) were considered to see if the designs provided whatever operating personnel would need to run the plant safely and efficiently. Approximately 100 specific findings were made, most of which pointed out details that were not adequately provided for in the preliminary work and should be worked out during final engineering.

Other findings and recommendations were such that changes and revisions in the concepts would make appreciable improvements in operability. Critical use of the results of this review will contribute significantly to excellence of the complete engineering for a prototype large breeder reactor power plant. In addition to the use of this review, it is recommended that the complete engineering of the large prototype include continuous participation of qualified operations and maintenance-oriented personnel with the responsibility to ensure valid and adequate provisions for these functions. *Project Managers: Joseph Matte III and R. K. Winkleblack*

MINAC: IN-PLANT RADIOGRAPHY

A progress report on prototype testing of a portable radiographic source for in-service inspection appeared in the EPRI Journal *(September 1980, p. 51). Since that time field equipment has been produced and used to perform what is perhaps one of the most demanding in-service inspections required of nuclear utilities—inspections inside containment vessels. The equipment, called Minac (miniaturized linear accelerator), has also been used to diagnose the cause and cure of power generation losses encountered by a utility during its normal plant operation. As a result of these demonstrations, Minac has been scheduled for mandated inspections through 1983, and a major EPRI NDE Center program has been undertaken to ensure that the equipment and training are available to member utilities and their inspection contractors when needed. The success of this project is a result of the innovative work of Schonberg Radiation, Inc., the prime contractor; the insights of Samuel Wenk of Southwest Research Institute, who developed the application specifications; and the field engineering of Rochester Gas and Electric Corp. (RG&E), which undertook the pioneering inspection and developed the procedures and supporting equipment that will be used. This report summarizes the events that have provided utilities with a totally new tool to ensure the safety and improve the availability of generating units.*

Historically, in-service radiography has been conducted by using radioactive isotopes, such as cobalt or iridium. These isotopes are limited by the source intensity available and by the physical size and weight of the shielding required during their transport. Thus, the quality of in-service radiography was generally substantially poorer than that obtained during component fabrication, where more powerful radiographic sources, such as linear accelerators, were in common use. In-service radiography of steel sections of over 8 in was a questionable proposition, even assuming that long exposure times were tolerable. EPRI examined and verified that linear accelerators of appropriately high energy could be reduced to sizes consistent with in-service needs by using higher radio frequency components than was the current practice (RP822). A complete, self-contained Minac radiographic system, consisting of a 3.5-ft^3 (0.1-m^3) radiation head, a modulator-power supply, and a control console, weighs less than 700 lb (317 kg). In contrast, the radiation head alone of a comparable, conventional linear accelerator weighs approximately a ton (907 kg).

Following qualification and reliability testing, Minac was first used by RG&E in May 1981 to perform a mandated inspection of a reactor coolant pump at RG&E's Ginna station. For this pioneering effort, the Minac head was mounted on a remote manipulator and placed inside the pump body. The welds of the pump, which varied from approximately 9 to 11.5 in (229 mm to 290 mm) in thickness, were then radiographed by placing X-ray film on the outside of the pump and switching Minac on for exposure and off

Table 2
OPERATING MODES AND OFF-NORMAL CONDITIONS

Event No.	Description
1	Startup from refueling conditions
2	Approach to rated full power
3	Steady full-power operation
4	Rapid change to partial power
5	Routine shutdown from rated power to hot standby (includes initiation of all decay heat removal systems)
6	Refueling
7	Reactor scram (includes subsequent transients and plant recovery)
8	Loss of off-site power
9	Loss of feedwater
10	Main turbine trip
11	Major sodium leak, primary heat transport system
12	Fuel element failure (includes highly irradiated fuel exposed to the sodium coolant)
13	Emergency cooling
14	Sodium pump failure
15	Water-to-sodium leak in the steam generator
16	One primary loop out of service (includes a review of events 1–15 for this condition)

during film placement and removal. More than 100 radiographs of better than 1% sensitivity were acquired during approximately 100 hours of Minac operation.

Although superficially simpler, the second Minac application conducted in July 1981 offered the complication of inspecting a plant operating at power at locations outside nuclear containment. Consolidated Edison Co. of New York believed that its Indian Point-2 unit power output was being affected by steam flow restrictions. Improper seating of main steam isolation valves was a suspected cause. Minac radiography established which valves were seating incorrectly and the required alterations. These timely data permitted valve adjustments during a brief outage scheduled earlier for other purposes. This inspection used only the self-contained Minac equipment: the head was carried to the valve location area by plant personnel. Because the plant was at power, this head was required to operate in over 140°F (60°C) ambient environment. At this extremely high temperature, problems of film integrity were encountered but no deterioration of equipment performance was observed.

The Minac X-ray output must be attenuated by about 10^7 before illuminating a personnel area at a nuclear site. Normally such attenuation is readily provided by the composite of the object being radiographed and the thick concrete containment vessel walls. But as the Indian Point-2 operation was outside containment, such convenient shielding was not readily available. Extensive care was required to ensure plant operating personnel were not exposed to Minac radiation. This process was successfully accomplished in a manner that demonstrated that the on-off capability of Minac, its tightly collimated beam, and other features facilitate minimal interruption of normal plant operations in comparison with isotopic sources.

The experience gained in these Minac operations is being consolidated in training programs and in equipment integration improvements by RG&E, the NDE Center, and Schonberg personnel in preparation for further pump inspections planned in 1981. These will be conducted by utilities and commercial inspection groups trained at the NDE Center. At the development level, a program has been initiated to upgrade the Minac output to 6 MeV and to further develop filmless radiography for field application. *Project Manager: M. E. Lapides*

CORRECTION

In the Authors and Articles section of the October 1981 *Journal,* Hui-Tsung Tang's title was listed incorrectly. Tang is manager of the Nuclear Power Division's Structural Integrity Subprogram.

New Contracts

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
ADVANCED POWER SYSTEMS				
RP2049-2	Evaluation of EDS Coal Liquid as a Utility Diesel Fuel	8 months	139.6	Southwest Research Institute *H. Schreiber*
RP2052-1	Combustion Turbine Power Systems Cycle Analysis	13 months	64.7	Waters and Associates *A. Cohn*
COAL COMBUSTION SYSTEMS				
RP364-3	Application of Two-Dimensional Code, PCGC-2, to Industrial Needs	21 months	130.0	Brigham Young University *J. Dimmer*
RP982-27	Technical and Economic Evaluation of the Avco-Ebara and Kureha Processes	2 months	195.8	Bechtel Group, Inc. *T. Morasky*
RP1260-26	Testing and Correlation of Fly Ash Properties With Respect to Pozzolanic Behavior, Part 1	15 months	43.9	University of California at Berkeley *D. Golden*
RP1260-27	Capacitive Cooling System for the ACT Facility, Phase 2-A	4 months	76.8	Chicago Bridge & Iron Co. *J. Bartz*
RP1260-28	Testing and Correlation of Fly Ash Properties With Respect to Pozzolanic Behavior, Part 2	15 months	13.7	Emcon Associates *D. Golden*
RP1261-4	Treatment of Recirculated Cooling Water	14 months	872.6	Stearns-Roger Engineering Corp. *W. Chow*
RP1263-6	Amine-Enhanced Photodegradation of PCBs	6 months	30.4	Battelle, Pacific Northwest Laboratories *R. Komai*
RP1263-7	Feasibility Study of Chemical Detoxification of PCB Capacitors	5 months	28.1	Acurex Corp. *R. Komai*
RP1266-22	Optimization Study of Natural Gas Used for Boiler Ignition and Flame Stabilization	7 months	34.1	Foster Wheeler Energy Corp. *J. Dimmer*
RP1404-3	Evaluation of the Commercial Viability of the ORNL Process for Recovery of Aluminum From Fly Ash	1 month	19.2	Arthur D. Little, Inc. *D. Golden*
RP1455-1	Effect of Coal Concentration and Magnesium Oxide on COM Slagging and Fouling	4 months	128.4	New England Power Service Co. *R. Manfred*
RP1807-03	10-MW High-Sulfur Coal Fabric Filter Pilot Plant, Phase 2	14 months	605.0	Stearns-Roger Engineering Corp. *W. Piulle*

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
RP1850-1	Coal Combustion By-Product Utilization	14 months	332.9	Michael Baker, Jr., Inc. *R. Komai*
RP1851-1	Sampling and Analysis for Priority Pollutants	16 months	232.8	TRW, Inc. *W. Chow*
RP1878-2	Evaluation of a Cubic Flow Nozzle for Thermal Performance Testing	7 months	22.7	Westinghouse Electric Corp. *T. McCloskey*
RP1883-1	Coal Pulverizer Fires and Explosions: Detection, Prevention, and Control	29 months	471.6	Riley Stoker Corp. *I. Diaz-Tous*
RP2114-1	Water Management at Zero Discharge Power Plants	10 months	98.8	CH2M-Hill, Consulting Engineers *W. Chow, R. Jorden*
ELECTRICAL SYSTEMS				
RP794-4	Development of a FIR Laser Instrument to Be Evaluated in a Cable Factory	39 months	1084.6	United Technologies Corp. *J. Porter*
RP1493-2	Behavior of Drilled Shaft Foundations During Undrained Uplift Loadings	17 months	97.8	Cornell University *P. Landers*
RP1498-2	Behavior of Circuit Breaker Contacts Subjected to Reduced Duration, Overrating Faults	4 months	15.7	Siemens-Allis, Inc. *N. Hingorani*
RP2015-1	Polysil* Transmission and Substation Structures	4 months	140.0	Hughes Supply, Inc. *J. Dunlap*
RP7876-16	Investigation of Powdered Cellulose in High-Voltage Electrical Apparatus	6 months	15.0	Battelle, Columbus Laboratories *M. Rabinowitz*
ENERGY ANALYSIS AND ENVIRONMENT				
RP940-4	Relation of Air Pollution to Mortality	1 year	92.1	Integrated Research Institute *R. Wyzga*
RP1009-10	Enhancement of DRI Coal Model Estimation of Coal Mining Cost Functions and Implementation	5 months	62.1	Data Resources, Inc. *T. Browne*
RP1224-7	Water Column Microcosm to Assess Effects of Trace Metals on a Cooling Pond	1 year	31.7	Portland State University *J. Huckabee*

*Polysil is an EPRI trademark

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
RP1483-3	Evaluation of Models of the Electricity Supply Industry	4 months	28.1	Charles River Associates, Inc. *S. Chapel*
RP1483-4	Evaluation of Models of the Electricity Supply Industry	4 months	30.0	Pugh-Roberts Associates *D. Geraghty*
RP1587-1	Methods for Evaluating Residential Conservation Programs	20 months	590.0	Arthur D. Little, Inc. *S. Braithwait*
RP1617-3	Prioritization of Chemical Emissions From Coal Gasification Facilities	7 months	48.7	Anthony V. Colucci & Associates, Inc. *J. Guertin*
RP1620-7	Workshop on Solid-Waste Disposal Handling and Environmental Assessment	10 months	44.2	Science Applications, Inc. *I. Murarka*
RP1630-20	Western Regional Air Quality Studies: Quality Assurance Services for Carbon Analyses	30 months	15.0	N. M. Research, Inc. *P. Mueller*
RP1633-1	Compensation Mechanisms in Fish Populations	11 months	105.0	Envirosphere Co. *R. Brocksen*
RP1727-1	Nitrogen Deposition on Forested Watersheds	3 years	527.3	TVA *J. Huckabee*
RP1908-1	Effects of Acid Precipitation on Agricultural Crops of the Midwest	3 years	892.5	Argonne National Laboratory *J. Huckabee*
RP1910-2	Relationship of Acid Deposition, Lake Acidification, and Fish	7 months	34.7	Western Aquatics, Inc. *R. Brocksen*
RP1947-1	Short-Course Application of Decision Analysis to Fuel Planning	8 months	71.2	Resources Planning Associates, Inc. *S. Chapel*
RP1956-1	Residential Elasticities by Time of Use	18 months	249.9	Laurits R. Christensen Associates *A. Faruqui*
RP1981-1	Fuel Supply Seminars—Coal	4 months	40.0	Pennsylvania State University *J. Platt*
RP2027-2	Development of a Methodology for Estimating the Costs of Air Quality Modeling Uncertainty	4 months	40.6	Systems Applications, Inc. *R. Wyzga*
ENERGY MANAGEMENT AND UTILIZATION				
RP1199-19	Simplified Evaluation Manual for CAES Power Plants	10 months	211.1	United Engineers & Constructors, Inc. *R. Schainker*
RP1676-3	Synthesize New Fuel Cell Electrolytes	11 months	49.9	Science Applications, Inc. *J. Appleby*
RP1832-2	Evaluation of Superconducting Magnetic Energy Storage System	19 months	133.8	Energy Management Associates, Inc. *T. Yau*
NUCLEAR POWER				
RP620-39	Composite Code for LMFBR Detailed Core Analysis	4 months	53.9	Barthold Associates, Inc. *W. Loewenstein*
RP891-18	DASS Design, Phase 2	5 months	35.3	S. Levy, Inc. *A. Long*
RP1163-3	Modular Modeling System-Integral System Test	4 months	76.9	Systems Control, Inc. *M. Toren*
RP1167-5	High-Temperature Behavior of Chemical Species in Water	2 months	15.1	Central Electricity Generating Board *D. Cubicciotti*
RP1167-6	Overview of BWR Water Chemistry	5 months	29.0	Jack Morton Productions, West, Inc. *M. Fox*
RP1543-6	Reliability of Piping and Fittings	8 months	20.4	Teledyne Engineering Services *R. Nickell*
RP1582-2	PWR Hybrid Power Shape Monitoring System	31 months	1090.0	Systems Controls, Inc. *A. Long*
RP1618-2	Examination of Intergranular Attack and Mechanism of Attack on Inconel 600 Tubing in Steam Generators	2 years	193.4	Babcock & Wilcox Co. *D. Cubicciotti*
RP1707-6	Specification of Seismic Data for Equipment Qualification Data Bank	3 months	26.9	Engineering Decision Analysis Co., Inc. *G. Sliter*
RP1754-4	Critical Flow Correlation Study	5 months	24.4	S. Levy, Inc. *L. Agee*
RP1803-4	Addition of the ALN 4000 to the BUCS Turbine Rotor Inspection System	16 months	300.0	Adaptronics, Inc. *S. Liu*
RP1939-1	Main Steam Isolation Valve Seat Resurfacing Tool Development	9 months	127.3	ESD Corp. *B. Brooks*
RP2055-3	Reconstituted Charpy Impact Specimens	6 months	72.4	Fracture Control Corp. *T. Marston*
RP2058-1	Crack Age Studies	1 year	109.5	Rockwell International *M. Fox*
RP2058-3	Measurement of Residual Stress With a Pulse Laser	5 months	49.5	General Electric Co. *W. Childs*
RP2062-2	Safeguards and Accountability of Spent Fuel in Compacted Form	4 months	14.8	INET Corp. *A. Carson*

New Technical Reports

Each issue of the *Journal* includes summaries of EPRI's recently published reports.

Inquiries on technical content may be directed to the EPRI project manager named at the end of each summary: P.O. Box 10412, Palo Alto, California 94303; (415) 855-2000.

Requests for copies of specific 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, government agencies (federal, state, local), or foreign organizations with which EPRI has an agreement for exchange of information. Others in the United States, Mexico, and Canada pay the listed price. Research Reports Center will send a catalog and complete price list (including foreign prices) on request.

Standing orders for free copies of reports in EPRI program areas or Technical Summaries of reports for each EPRI technical division may be placed by EPRI member utilities, libraries of U.S. federal, state, and local government agencies, and the official representative of any foreign organization with which EPRI has an information exchange agreement. For details, write to EPRI Technical Information Division, P.O. Box 10412, Palo Alto, California 94303.

Microfiche copies are available from National Technical Information Service, P.O. Box 1553, Springfield, Virginia 22151.

ADVANCED POWER SYSTEMS

Baseline Data on Utilization of Low-Grade Fuels in Gas Turbine Applications

AP-1882 Final Report (RP1079-1, -2, -3); Vol. 1, $12.50; Vol. 2, $8.00; Vol. 3, $11.00

A test was conducted in twin 260-MW (e) combined-cycle units to compare the costs and performance factors of firing distillate and residual fuels. One unit burned No. 2 oil and the other a blended low-sulfur residual oil. Volume 1 characterizes the costs, reliability, and operating factors associated with firing each fuel. Volume 2 compares the corrosion of turbine parts. A metallographic evaluation of combustion turbine hot components is described, and the corrosive effects of vanadium compounds are considered. Volume 3 presents results on baseload emission levels with and without afterburners in service, with and without water injection, and following a turbine wash. A brief series of additional tests made at reduced operating loads is also described. The contractors are Florida Power & Light Co., Westinghouse Electric Corp., and KVB, Inc. *EPRI Project Manager: Henry Schreiber*

Water-Cooled Gas Turbine Development Program

AP-1889 Final Report (RP234-3); Vol. 1, $20.00; Vol. 2, $45.50

Volume 1 summarizes the results of a project to establish the viability of water cooling as a means of achieving higher firing temperatures and increased fuel flexibility in utility gas turbines. It describes several areas of turbine design and provides details on water-cooled nozzles and buckets, the water supply system, and the ceramic combustor. Volume 2 collects several topical reports that document individual tasks performed at various test facilities for this program. It describes the experimental procedures, test rigs, and calculation methods used and presents data tables. The contractor is General Electric Co. *EPRI Project Manager: Arthur Cohn*

U.S. Coal Test Program on BGC-Lurgi Slagging Gasifier

AP-1922 Final Report (RP1267-1); $21.50

A test using caking coals was conducted in a 6-ft-diam, 350-t/d gasifier. This report describes the equipment, instrumentation, and controls; bed behavior; plant behavior in flow controls; and post-run inspections. It also discusses coal gas particulates and oxygen plant dynamics. The contractor is British Gas Corp. *EPRI Project Manager: John McDaniel*

Process Development for Improved SRC Options: Kerr-McGee Critical Solvent De-ashing and Fractionation Studies

AP-1932 Final Report (RP1134-2); $11.00

A coal liquefaction process incorporating critical solvent de-ashing was demonstrated in continuous bench-scale units. The de-ashing and fractionation of SRC-I and short-residence-time vacuum bottoms are described, as well as the addition of light SRC (the fractionated portion of the soluble coal product) to improve liquefaction solvent quality. Soluble-coal-product recovery studies and work to determine the operating conditions required to produce light SRC are also covered. The contractor is Kerr-McGee Corp. *EPRI Project Managers: C. J. Kulik and H. E. Lebowitz*

Advanced-Cooling Full-Scale Engine Demonstration

AP-1934 Final Report (RP1319-3); $18.50

This report describes a program to demonstrate the advantages of advanced fabrication techniques for convectively cooled airfoils for utility combustion turbines. It covers the design and fabrication of test hardware, the advanced-cooling-rig test, and aerodynamic and cooling performance parametric studies. The contractor is United Technologies Corp. *EPRI Project Manager: Arthur Cohn*

Repowering Oil-Fired Boilers With Combustion Turbines Fired With Gas From Coal

AP-1937 Final Report (RP986-6); $18.50

The repowering of oil-fired reheat steam plants with combustion turbines and coal gas from the Texaco oxygen-blown gasifier was studied. Plant configurations, equipment changes, and performance were determined for a nominal 333-MW plant in three repowering cases: (1) coal gas supplied by pipeline (remote source), (2) complete integration of the gasification system with the power plant, and (3) partial integration of the gasification system wherein the boiler retains oil firing. The contractor is Westinghouse Electric Corp. *EPRI Project Manager: B. M. Louks*

Preliminary Oxygen Plant Assessment for Texaco-Gasifier-Based Gasification–Combined-Cycle Systems

AP-1942 Final Report (RP239-5); $8.00

This report, a supplement to an earlier report on commercial oxygen production technology (AP-1674), characterizes an oxygen supply system configuration for use with a Texaco-gasifier-based gasification–combined-cycle system. The selected supply system is described, and recommendations for future oxygen supply system studies are outlined. The contractor is Union Carbide Corp. *EPRI Project Managers: E. L. Force and B. M. Louks*

Large Wind Turbine Generator Performance Assessment

AP-1959 Interim Report (RP1348-1); $12.50

This technology status report summarizes recent data from federal government and private development and test programs on large wind turbines (rated power of 100 kW or higher). The data presented are current as of October 1980. The contractor is Arthur D. Little, Inc. *EPRI Project Manager: F. R. Goodman, Jr.*

COAL COMBUSTION SYSTEMS

Study of Gypsum Crystal Nucleation and Growth Rates in Simulated Flue Gas Desulfurization Liquors

CS-1885 Final Report (RP1031-2); $9.50

This report describes the kinetics of gypsum crystal nucleation and growth rates that were measured in flue gas desulfurization scrubber liquids. The variables studied include parent seed crystal size and mass; additives (citric acid, adipic acid, sodium dodecylbenzene sulfonate, and polyacrylate); and pH level. The contractor is the University of Arizona. *EPRI Project Manager: Dorothy Stewart*

Studies of In-Bed Corrosion in a Pressurized Fluidized-Bed Combustor

CS-1935 Final Report (RP979-3); $36.50

Corrosion of candidate in-bed tube materials was investigated in connection with a 1000-h test program in a pressurized fluidized-bed combustion facility. This report describes the test facility, the nominal operating conditions, and the corrosion probes. Results from metrology and metallographic examinations of the corrosion are in the appendixes. Conclusions and recommendations are included. The contractor is Fluidised Combustion Contractors, Ltd. *EPRI Project Manager: John Stringer*

Vibration Signature Analysis and Acoustic Emission Monitoring at Brayton Point

CS-1938 Final Report (RP934-1); $21.50

The on-line monitoring techniques of vibration signature analysis and acoustic emission detection are summarized, including sensor selection and location, spectrum analysis techniques, computation techniques, and display devices. Specific plant equipment failures are described, and the appropriate vibration and acoustic emission data are analyzed to assess any deviations before failure. The contractor is Rockwell International Corp. *EPRI Project Managers: A. F. Armor and J. B. Parkes*

Neutron Activation Analysis of Turbine Deposits

CS-1958 Interim Report (RP1409); $8.00

This report presents the basic design of a nonintrusive system using the associated-particle time-of-flight technique to detect the inelastic gamma rays induced by 14-MeV neutrons incident upon corrosion deposits on the blades of an operating steam or combustion turbine. Measurements of turbine blade corrodents and the analysis of combustion and steam turbine blade signals are described. Conclusions and potential applications of the system are also discussed. The contractor is Consolidated Controls Corp. *EPRI Project Managers: K. P. Lehner and J. B. Parkes*

Steam Turbine Blades: Considerations in Design and a Survey of Blade Failures

CS-1967 Topical Report (RP912-1); $12.50

This report details design aspects that control stresses and vibrations to which steam turbine blades are subject during service. Specific topics include (1) thermomechanical considerations and material selection criteria for blade design; (2) sources of vibratory excitation and blade response, the resulting stress levels and load histories, and design features to minimize or resist these stresses; and (3) blading alloy properties of concern to blade designers and parameters for use in fatigue testing. Also presented are the results of a blade failure survey. The contractor is Westinghouse Electric Corp. *EPRI Project Manager: R. I. Jaffee*

Control of Fan Erosion in Coal-Fired Power Plants: Phase 1

CS-1979 Final Report (RP1649-4); $14.00

Ways of controlling fly ash erosion in power plant fans were investigated. The study examined the erosivity of fly ash from bituminous and subbituminous coal and lignites, the factors in obtaining highly erosion-resistant coatings, and the erosion resistance of advanced fly ash armoring systems. A computer model was developed and used in comparing the erosion resistance of four basic centrifugal fan designs and in diagnosing operating problems. Two case studies are presented to illustrate the model's use. The contractor is Westinghouse Research Laboratories. *EPRI Project Manager: John Stringer*

Monitoring the Fixed-FGD-Sludge Landfill, Conesville, Ohio: Phase 2

CS-1984 Interim Report (RP1406-2); $12.50

This report presents results from ongoing evaluations of the first full-scale application of the IU Conversion Systems stabilization-fixation system for flue gas desulfurization sludge. Stabilized sludge has been landfilled since 1977 at the Conesville (Ohio) power station. Phase 2 work entails continual well sampling and water quality comparisons, sludge sampling and testing, documentation of disposal operation problems, and evaluation of the overall fixation system. Two further reports on Phase 2 are planned. The contractor is Michael Baker Jr., Inc. *EPRI Project Manager: D. M. Golden*

Assessment of Rotor-Bearing Dynamics: A Planning Study for the Utility Industry

CS-1990 Final Report (RP1648-2); $14.00
CS-1990-SY Summary Report; $5.00

These reports present the results of a study to determine the current state of the art of rotor and bearing dynamic analyses of large steam turbine generators. Current U.S. capabilities and practices are reviewed, U.S. utility needs with regard to rotor-vibration-related problems are assessed, and an R&D plan with specific recommendations to address those needs is described. The contractor is Mechanical Technology, Inc. *EPRI Project Managers: T. H. McCloskey and J. B. Parkes*

Nondestructive Evaluation of Turbines and Generators: 1980 Conference and Workshop

WS-80-133 Proceedings; $39.50

A workshop on the nondestructive evaluation (NDE) of steam turbines and generators was held in Washington, D.C., in October 1980 by EPRI and Potomac Electric Power Co. It was directed at utility problems in evaluating turbine generators and making repair and run/retire decisions. The sessions covered industry problems, turbine NDE, generator NDE, EPRI projects, vibration signature analysis, and new developments. The contractor is Aptech Engineering Services. *EPRI Project Manager: A. F. Armor*

ELECTRICAL SYSTEMS

Light-Fired Thyristor Development

EL-1916 Interim Report (RP567-1); $11.00

A light-fired thyristor for use in high-voltage, high-power utility applications was developed and demonstrated in one phase of a static volt-ampere-reactive generator. The development and testing of each part of the system are detailed, as well as the building, installation, and early evaluation of the 13.8-kV, 1200-A bidirectional switch. The contractor is Westinghouse Electric Corp. *EPRI Project Manager: G. I. Addis*

Conductor Fatigue Life Research

EL-1946 Final Report (RP1278-1); $12.50

A study was undertaken to evaluate the effects of reducing vibration amplitudes of conductors that had been minimally damaged by eolian vibration (a wind-induced phenomenon in which conductors vibrate in a low-amplitude mode, leading to fatigue damage to individual conductor strands). Tests using two different amplitude reductions on three different conductors are described. The results indicate that amplitude reduction arrested fatigue strand breakage in each case. The contractor is Auburn University. *EPRI Project Manager: J. W. Porter*

Development of a Vacuum Arc Fault Current Limiter

EL-1947 Final Report (RP993-1); $11.00

The operating principles and characteristics of two vacuum arc devices under development for fault-current-limiting applications are summarized: the vacuum arc fault current limiter and the magnetically controlled vacuum arc switch. The repetitive voltage spiking phenomenon that occurs in the first device is described, and techniques for enhancing current limiting by enhancing spiking development are discussed. The contractor is the State University of New York at Buffalo. *EPRI Project Managers: J. W. Porter, R. E. Kennon, and I. Vancers*

Nb_3Ge-Based 1-m Power Transmission Cable: Material Development, Cable Fabrication, and Cable Performance Tests

EL-1948 Final Report (RP7855-1-2); $9.50

This report describes the third phase of a program to develop Nb_3Ge conductors for power transmission applications. Details of the fabrication and testing of a 1-m-long coaxial cable constructed from 87 m of Nb_3Ge-clad tape wound in a double-double-helix design are presented. The results of a development program to improve the superconducting performance are also included. The contractor is Los Alamos National Laboratory. *EPRI Project Manager: Mario Rabinowitz*

Investigation of Geomagnetically Induced Currents in the Proposed Winnipeg–Duluth–Twin Cities 500-kV Transmission Line

EL-1949 Final Report (RP1205-1); $15.50

The effects of geomagnetically induced currents (GIC) on a new 749-km, 500-kV ac transmission line were investigated. GIC effects on the operation of the line, equipment connected directly to the line, and power systems connected to the line were considered. The study concluded that GIC can have a substantial impact on equipment performance and on the power system. Potentially troublesome equipment and system conditions (both steady state and transient) were identified. The contractors are Minnesota Power & Light Co. and the University of Minnesota. *EPRI Project Manager: J. W. Porter*

Environmental Chamber for the Examination of Transmission Line Electric Field and Corona Effects

EL-1953 Final Report (RP68-6); $8.00

This report assesses the feasibility of using an environmental chamber for the examination of transmission line electric field and corona effects. Tests relating to such elements as ground-level electric field strength, corona starting voltage, conductor surface conditions, and corona mechanisms and losses were conducted in a chamber, and the results are reviewed. Also discussed are chamber design considerations, preliminary specifications, supply requirements, and guidelines for instrumentation. The contractor is Ohio State University. *EPRI Project Manager: R. E. Kennon*

Human Factors Review of Electric Power Dispatch Control Centers

EL-1960 Interim Report (RP1354-1); Vol. 1, $9.50; Vol. 2, $29.00

A human factors survey of 13 utility control centers was conducted. The survey evaluated the information available to operators, the physical interface between the operators and the power systems, and the operational setting. Particular emphasis was placed on the design of the cathode-ray tube interface, the data base, facility lighting, training, manning, and work stress. Areas for further study were identified. Volume 1 summarizes the survey results, and Volume 2 presents them in detail. The contractor is Lockheed Missiles & Space Co., Inc. *EPRI Project Managers: D. F. Koenig and C. J. Frank*

Research to Develop Guidelines for Cathodic Protection of Concentric Neutral Cables

EL-1970 Interim Report (RP1049-1); Vol. 1, $15.50; Vol. 2, $21.50

This report describes an effort to develop cathodic protection systems for the concentric neutral conductors on existing cable installations. It presents and analyzes field and laboratory data and correlates the corrosion found at various locations on underground distribution cables with the data. It also provides details on installed experimental protection systems. Volume 1 includes descriptions of the problem, tests, data, and analysis. Volume 2 consists of four appendixes with supporting drawings and graphs. The contractor is Pacific Gas and Electric Co. *EPRI Project Manager: T. J. Kendrew*

Component Outage Data Analysis Methods

EL-1980 Final Report (RP1468-1); Vol. 1, $18.50; Vol. 2, $12.50

This report describes work to develop methods for improving the quality of outage data analysis for power equipment. Statistical techniques were evaluated and applied to utility outage data to illustrate their use. Volume 1 discusses the physical characteristics of generation outages, practical limitations on generation outage data analysis, forced partial generation outages, and the prediction of equipment availability from a severely limited data base. Volume 2 discusses the concepts and tools of classical statistics that are of primary value to outage data analysis. The contractor is Westinghouse Electric Corp. *EPRI Project Manager: N. J. Balu*

Contamination Flashover of HVDC Insulators

EL-2016 Final Report (RP848-1); $14.00

An integrated field and laboratory study was conducted to investigate the mechanism of flashover of contaminated insulators under HVDC conditions. Topics discussed include the clean-zone phenomenon and an explanatory theory, a method to predict insular performance in any location by knowing the composition of contaminants in the area, and the effects of weather on insulator performance. Work on the voltage distribution along a string of insulators led to the use of internal grading to improve the performance of the insulator string. The contractor is the University of Southern California. *EPRI Project Manager: John Dunlap*

HVDC Ground Electrode Design

EL-2020 Final Report (RP1467-1); $32.00

This report presents a state-of-the-art study of HVDC ground electrode design. It covers the background of ground electrode theory; siting of ground electrodes; design procedures, including formulas and sample designs; techniques for mitigating ground current effects; and testing procedures to determine operating conditions of in-service electrodes. The results of a survey of all ground electrodes built up to mid-1981 are also presented. The contractor is International Engineering Co., Inc. *EPRI Project Manager: John Dunlap*

ENERGY ANALYSIS AND ENVIRONMENT

Regional Load Curve Models: Scenario and Forecast Using the DRI Model

EA-1672 Final Report, Vol. 3 (RP1008); $23.00

A project was undertaken to develop and demonstrate models capable of producing long-term forecasts of hourly load curves for 32 regions of the continental United States (representing approximately 95% of U.S. electricity consumption). This volume presents illustrative forecast results produced by the Data Resources, Inc., model. It includes a model overview, reviews earlier model validation exercises, and outlines changes made in the model before the forecast. The specification and estimation of the model were described in detail in Volume 1, published earlier. The contractor is Data Resources, Inc. *EPRI Project Managers: Ahmad Faruqui and A. G. Lawrence*

A Generation Planning System: Methodology and Case Study

EA-1807 Final Report (RP950-1); $26.00

This report describes the development of a generation planning model, an optimization model based on linear programming techniques, and illustrates its potential application with a case study on a synthetic utility. A model subprogram calculates loss-of-load probability for expansion patterns with various combinations of candidate generating units. These data are used in a regression analysis to determine reserve-margin requirements associated with the addition of each generating unit, and the regression equation is incorporated into the linear program. The contractor is Gordian Associates, Inc. *EPRI Project Manager: J. K. Delson*

Models for Forecasting Energy Use in the U.S. Farm Sector

EA-1956 Final Report (RP682-1, -2); Vol. 1, $17.00; Vol. 2, $12.50

This report describes a project to develop econometric models for forecasting electricity and petroleum demand in the U.S. agricultural sector. Volume 1 describes (1) the input and output series constructed from raw data sources, and (2) the estimation and testing of alternative models. Three different functional forms of varying complexity were specified for the structural cost function, and the three models' predictions of energy demand in short- and long-term ex ante forecasting experiments were compared. Volume 2 describes subsequent model improvement work and linkage of the agricultural model with the Wharton annual forecasting model of the U.S. economy. The contractors are Data Resources, Inc., and Laurits R. Christensen Associates, Inc. *EPRI Project Managers: S. D. Braithwait and L. J. Williams*

Supply Problems in the Solar Heating and Cooling Industry

EA-1957 Final Report (RP1031-1); $6.50

This report summarizes supply problems in the solar heating and cooling industry, such as future distribution channels and costs. It reviews the components of solar costs, including collectors, marketing, installation, and operation and maintenance. Public policy initiatives that may critically influence the development of solar energy are outlined, and the impact of competing energy sources on solar heating economics is examined. The contractor is DHR, Incorporated. *EPRI Project Manager: R. J. Urbanek*

Choice and Utilization of Energy-Using Durables

EA-1961 Proceedings (RP1050); $26.00

This volume contains eight reports presented at an EPRI-sponsored workshop held in November 1979 in Boston on choice and utilization of energy-using durables. Topics include (1) choice of heating, ventilating, and air conditioning systems in terms of capital cost, price, and weather; (2) an integrated approach to consumer choice and utilization from a utility-function specification; (3) econometric methodology issues in estimating appliance utilization models; (4) household patterns of car ownership; and (5) the demand for electric cars. The contractor is the University of Arizona Engineering Experiment Station. *EPRI Project Managers: S. D. Braithwait and A. G. Lawrence*

Evaluating R&D Options Under Uncertainty

EA-1964 Final Report (RP1432-1); Vol. 1, $9.50; Vol. 2, $9.50; Vol. 3, $11.00

Efforts to develop and apply analytic methods to important EPRI resource allocation problems are described. Volume 1 presents a quantitative framework for examining the appropriate emphasis of incremental funding aimed at improving electric power generation technologies. The methodology was applied to current pulverized-coal technology, and the results are presented. Volume 2 describes an analysis of commercialization strategies for atmospheric fluidized-bed combustion plant development. The analytic framework, data assessment, and results are summarized. Volume 3 describes an electric utility generation expansion model developed for use in R&D planning under uncertainty. This model was used in the study summarized in Volume 1. The contractor is Applied Decision Analysis, Inc. *EPRI Project Manager: S. S. Sussman*

Proceedings: Workshop on Cycling and Effects of Toxic Substances

EA-1988 Proceedings (RP1822-1); $11.00

A workshop on the cycling and effects of toxic substances in ecological systems was held in October 1980 in Carmel, California, to suggest a research program that would be responsive to utility needs. A broad conceptual framework and guiding principles for such research were developed, and 13 specific projects were identified and ranked. The workshop results will be used as a planning base for EPRI's toxic substances subprogram. The contractor is International Research and Technology Corp. *EPRI Project Manager: R. W. Brocksen*

Assessment of Optimum Aquatic Microcosm Design for Pollution Impact Studies

EA-1989 Final Report (RP1224-1); $15.50

A study was undertaken to assess the ability of a microcosm system to simulate the behavior of pelagic zones of lakes and to determine its usefulness as an environmental assessment tool. Key problem areas in microcosm design and operation were examined in a series of experiments. The conditions that were varied in these tests included the size and shape of microcosm containers, the degree of aeration and water agitation in the microcosms, and the degree of surface growth of algae on the containers' inner walls. The contractor is Lawrence Berkeley Laboratory. *EPRI Project Managers: R. W. Brocksen and R. K. Kawaratani*

Evaluation of CHESS: New York Asthma Data, 1971–1972

EA-1994 Final Report (RP681-1, RP1642-1); Vol. 1, $15.50; Vol. 2, $26.00

This report evaluates previous research on the health effects of air pollution and analyzes the appropriateness of using asthma as a health indicator. It continues the work of EA-450, which evaluated 1970–1971 New York asthma data. Volume 1 describes shortcomings discovered through an examination of the data and the experimental protocol and summarizes results of a statistical reanalysis of the data. Volume 2 contains appendixes of data tables. The contractors are Flow Resources Corp. (now General Resources Corp.) and Roth Associates, Inc. *EPRI Project Manager: R. E. Wyzga*

Assessment of Emerging Energy Sources

EA-2023-SY Summary Report (RP1482-1); $8.00

This report summarizes the results of a broad review and analysis of the commercialization potential of seven emerging energy sources: tight gas sands, heavy oil, methane from geopressured aquifers, oil shale, enhanced oil recovery, advanced coal mining technologies, and underground coal gasification. Each was evaluated with respect to resource size and characteristics, technical and economic performance, relevant energy market growth rates, logistical considerations, development lead times, and regulatory and institutional factors. The contractor is Booz, Allen & Hamilton, Inc. *EPRI Project Manager: R. J. Urbanek*

Workshop Proceedings: World Oil and Natural Gas Supplies

WS-79-192 Proceedings; $23.00

EPRI sponsored a workshop on world oil and gas supplies in June 1979 in Reston, Virginia, to address the interrelationships between economics, politics, resources, and technologies that will influence future supplies. This report contains the papers presented and summaries of the workshop discussions. *EPRI Project Manager: J. H. Eyssell*

ENERGY MANAGEMENT AND UTILIZATION

Preliminary Design Study of Underground Pumped Hydro and Compressed-Air Energy Storage in Hard Rock

EM-1589 Final Report (RP1081-1); 23 vols. (priced per vol.)

These volumes document a preliminary design study of underground pumped-hydro and compressed-air energy storage plants with caverns excavated out of hard rock. The study entailed these tasks: establishing design criteria and analyzing plant impacts on the power system, selecting a site and establishing site characteristics, formulating design approaches, assessing environmental and safety aspects, and preparing preliminary plant designs. The primary objective was to develop sufficiently detailed engineering designs for each plant to establish construction costs and schedules, performance and operating characteristics, potential construction and operating risks, and environmental, social, and licensing issues. Volume 1 presents an executive summary of the project. Detailed results are presented in Volumes 2–13 and 10 appendixes. The contractor is Potomac Electric Power Co. *EPRI Project Manager: Antonio Ferreira*

Effect of Alternative Fuels on the Performance and Economics of Dispersed Fuel Cells

EM-1936 Final Report (RP1041-7); $15.50

The effects of five alternative fuels (natural gas, coal-derived medium-Btu gas, methanol, ethanol, and naphtha) on the performance and economics of conceptual phosphoric acid fuel cell power plants were assessed. On the basis of fuel properties and fuel cell requirements, preliminary specifications for fuel-processing systems were prepared. Vendor-supplied cost, performance, and operational data on fuel-processing systems were analyzed to define 10 fuel cell power plant configurations using the alternative fuels. The contractor is Westinghouse Electric Corp. *EPRI Project Manager: E. A. Gillis*

Utilization of Waste Heat From Major Transformer Substations

EM-1968 Final Report (RP1274-1); Vol. 1, $15.50; Vol. 2, $9.50; Vol. 3, $14.00

A study was undertaken to define the technical and economic merits of using substation transformer waste heat for space-heating purposes. Volume 1 presents the results of a generic study of system design criteria and economics. Volume 2 describes a site-specific application based on these results. Volume 3 presents the data used in the generic study. The contractor is Seattle City Light. *EPRI Project Manager: J. S. Brushwood*

Cogeneration Potential: Enhanced Oil Recovery

EM-1996 Final Report (RP1276-7); $9.50

This report presents a preliminary evaluation of the U.S. potential for generating electric power in connection with producing steam for the enhanced recovery of oil. It includes design information on representative cogeneration systems suitable for thermally enhanced recovery—semitransportable gas turbine, semitransportable steam turbine, and central plant multiple gas turbine. Incentives and obstacles to cogeneration use, attitudes of utility companies and petroleum producers, and associated environmental problems are discussed. The contractor is RMR Associates. *EPRI Project Managers: S. D. Hu and R. L. Mauro*

NUCLEAR POWER

Numerical Simulation of BWR Suppression Pool Dynamics

NP-1856 Final Report, Vols. 1–3 (RP965-3); $17.00

This report summarizes hydrodynamic processes involving complicated free-surface configurations. SOLVA-VOF, a new numerical method developed to handle such problems, is described and evaluated by comparisons with laboratory test data. Important thermodynamic and hydrodynamic phenomena (e.g., vent clearing, bubble growth, and collapse) and the effects of such parameters as suppression pool geometry, vent size, submergence, and compressibility are discussed. The contractor is the University of California. *EPRI Project Managers: John Carey and Avtar Singh*

Design and Fabrication of an X-Ray Stress Analyzer

NP-1873 Final Report (RP823-1); $9.50

This report presents a two-phase study to design and fabricate an X-ray stress analyzer for measuring residual stress in austenitic stainless steel pipes. The contractor is the Denver Research Institute. *EPRI Project Manager: J. R. Quinn*

Effects of Heat Treatment on the Passive Behavior of Ni-Cr-Fe Alloys in High-Temperature Water

NP-1884 Final Report (RP1170-1); $18.50

Five electrochemical test programs were conducted to investigate the effects of thermal treatment, environmental variations, and stress on the corrosion resistance of Inconel Alloys 600 and 690 in simulated BWR and PWR systems. The fundamental electrochemical corrosion behavior of these systems and the effects of dissolved oxygen on the corrosion potential are described. A possible mechanism of surface scale formation is discussed, and details are provided on the intergranular and stress corrosion test results. The contractor is The International Nickel Co. *EPRI Project Manager: J. C. Danko*

Studies of Transition-Boiling Heat Transfer With Saturated Water at 1–4 Bar

NP-1899 Final Report (RP688-1); $18.50

This report presents results from steady-state and transient transition-boiling heat transfer tests in both a round tube and an annular test section. Several phenomenological studies are also detailed—void fraction measurement, visual and photographic observation, and an examination of wall temperature fluctuations. An upgraded transition-boiling correlation is presented. The contractor is the University of Cincinnati. *EPRI Project Manager: K. H. Sun*

Analysis of ThO_2–UO_2 Isotopics From Indian Point-1

NP-1919 Final Report (RP1254-1); $12.50

Calculated isotopic concentrations were compared with measured concentrations for 13 samples from the first core of the Indian Point-1 PWR. The CPM collision probability code was used to make the calculations. The models are described in detail, including the geometric assumptions, composition homogenization, treatment of fuel impurities, and CPM input. The modifications required to provide thorium-cycle depletion capability in CPM, the calculation procedures used, and the results are discussed. The contractor is Babcock & Wilcox Co. *EPRI Project Manager: W. J. Eich*

REFUEL: A Computer Program for Automated BWR Fuel Management

NP-1920 Final Report (RP1177-1); $18.50

This report describes the REFUEL computer program, which was developed for determining optimal BWR refueling patterns. Details are provided on the nuclear model and its validity, the method of optimization, code applications, and energy costs. Comparisons of core power distribution and burnups with standard programs indicate that the REFUEL nuclear model has the requisite accuracy. The contractor is the University of Cincinnati. *EPRI Project Manager: W. J. Eich*

Engineering Approach for Elastic-Plastic Fracture Analysis

NP-1931 Topical Report (RP1237-1); $18.50

Formulas, charts, and background material that allow calculation of safety margins in ductile structures containing flaws are presented. The report covers (1) the analytic foundations and limitations of using the J-integral in ductile fracture analysis, (2) the fully plastic solutions obtained to date and the solutions for specimen geometries, (3) cylindrical geometries, and (4) the nozzle corner flaw model. Numerous examples demonstrating the use and accuracy of the approach are included. The contractor is General Electric Co. *EPRI Project Managers: D. M. Norris, Jr., R. L. Jones, and T. U. Marston*

Steam Generator Sludge Pile Model Boiler Testing

NP-1941 Final Report (RPS119-1); $11.00

This report presents the results of a study to identify and explain the thermal and hydraulic transport processes occurring in sludge piles on the secondary side of PWR steam generators. Details are provided on the physical and chemical properties of sludges, the development of simulated sludges, the extent of sludge dryout, and an analytic model for determining the position of dryout within the sludge. The results from tests and the analytic model both indicate that relatively small amounts of sludge can promote liquid-deficient heat transfer. The contractor is Westinghouse Electric Corp. *EPRI Project Manager: D. A. Steininger*

Optical Scanner System for Internal Inspection of Steam Generator Tubes

NP-1944 Final Report (RPS103-2); $12.50

This report describes the design and performance of a high-resolution system for inspecting steam generator tubes. Design and performance data from the prototype and low-resolution scanners are compared with data from the high-resolution scanner to indicate the system's evolution. A technical description of the system and its operation, a set of performance data on simulated defects, and recommendations for field applications are presented. The contractor is Science Applications, Inc. *EPRI Project Manager: G. W. DeYoung*

Phased-Mission System Reliability Analysis

NP-1945 Final Report (RP1233-2); Vol. 1, $12.50; Vol. 2, $12.50

Volume 1 presents new concepts and terminology relating to phased-mission system analysis, a reliability analysis method for dynamic engineering systems found in the nuclear power industry. Techniques for calculating system reliability, availability, and expected number of failures are presented and demonstrated for an analysis of a PWR emergency core cooling system during a loss-of-coolant accident. Volume 2 is a user's guide for the PHAMAS computer code, a program for quantitative analysis of phased missions. The program's methodology and input and output are described, and a sample problem is presented. The contractor is the University of Tennessee. *EPRI Project Manager: B. B. Chu*

Assessment of Precision Gamma Scanning for Inspecting LWR Fuel Rods

NP-1952 Final Report (RP1702-4); $9.50

This report evaluates the reconstruction of radial two-dimensional distributions of fission products by using projections obtained by nondestructive gamma scanning. It discusses the technique's theoretical background, scanning system components, the use of filtered backprojection, and problems. Appendixes cover the effects of statistical uncertainties and slit collimation and compare four construction techniques. The contractor is Los Alamos Scientific Laboratory. *EPRI Project Manager: Howard Ocken*

Analysis of Fission Gas Release Measurements Using the COMETHE IIIJ and FCODE-Alpha Computer Codes

NP-1954 Final Report (RP1702-2); $9.50

This report presents the results of a study that compared the predictions of two fuel rod performance codes with experimental data. The first phase of the study compared the predictive capabilities of the COMETHE IIIJ and FCODE-Alpha computer codes. The second phase used an updated version of COMETHE to predict fuel rod central temperature, rod-to-cladding gap, mean cladding hoop strain, and rod fission gas release for a number of PWR and BWR fuel rods for which experimental data are available. The contractor is Science Applications, Inc. *EPRI Project Manager: Howard Ocken*

Estimation of Diffusion Coefficients for Electrolytes in Hot Water

NP-1963 Topical Report (RPS146-1); $8.00

This report documents a literature search for diffusion data and the calculation of diffusion coefficients for species of interest. Diffusion coefficients were calculated for sodium chloride, trace amounts of hydrochloric acid in the presence of sodium chloride, divalent metal chlorides, and sodium phosphates. Inaccuracies and a confidence ranking are given. The results have important implications for possible resolution of current steam generator problems. The contractor is Westinghouse Electric Corp. *EPRI Project Manager: C. E. Shoemaker*

Design and Construction of Model Steam Generators for Corrosion Testing of Alternative Materials

NP-1965 Topical Report (RP623-4); $12.50

This report describes the design and construction of two model steam generators built to test the corrosion resistance of contemporary and alternative steam generator materials under secondary-water conditions. The criteria for selecting alternative materials are discussed, and the metallurgical properties of the materials are summarized. Extensive thermal-hydraulic analyses of the models are also presented. The contractor is Combustion Engineering, Inc. *EPRI Project Manager: C. E. Shoemaker*

Structural Mechanics Program: Progress in 1980

NP-1969-SR Special Report; $12.50

This report reviews the progress made in 1980 in EPRI's Structural Mechanics Program and discusses the interrelationships of the projects. The program is addressing 18 research topics under more than 40 contracts. An up-to-date account of structural mechanics issues is provided, and progress toward resolving them is discussed. Plans for the 1981 program are also included. *EPRI Project Manager: T. U. Marston*

Achievements, Findings, and Lessons of the Phénix LMFBR Power Plant Experience

NP-1972 Final Report (RP1704-8); $8.00
NP-1973 Final Report; $20.00

These reports review published information on the French Phénix LMFBR plant. NP-1972 is an executive summary, and NP-1973 presents the information in detail. They emphasize those aspects of the Phénix experience that are of particular interest in the consideration of LMFBRs for large central station power generation. Plant construction, startup, operation, and maintenance activities are discussed. The contractor is Rockwell International Corp. *EPRI Project Manager: Joseph Matte III*

Steam Generator Chemical Cleaning: Demonstration Test No. 2 in a Pot Boiler

NP-1976 Topical Report (RPS128-1); $11.00

This report documents the results of a laboratory test of the EPRI Mark II chemical cleaning process in a four-tube pot boiler. It describes the test, the secondary-water chemistry specifications, and the results of destructive and nondestructive examinations conducted before the chemical cleaning. The contractor is Combustion Engineering, Inc. *EPRI Project Manager: C. S. Welty, Jr.*

Evaluation of Proposed Control Room Improvements Through Analysis of Critical Operator Decisions

NP-1982 Final Report (RP891); $17.00

This report presents a retrospective analysis of decision making by nuclear power plant operators during four recent off-normal events. It also provides a descriptive model of operator decision making and an appraisal of how decision making may be affected by different categories of improvements—changes in staff organization and training, improved controls and displays, and computerized support systems. An overview of the study methodology is included. The contractor is Bolt, Beranek & Newman, Inc. *EPRI Project Manager: A. B. Long*

Workshop Proceedings: U-Bend Tube Cracking in Steam Generators

WS-80-136 Proceedings; $27.50

This report contains papers presented at a workshop on the cracking of Inconel Alloy 600 U-bend tubes in steam generators, sponsored by the Steam Generator Project Office in August 1980 in Denver. The papers discuss concerns about cracking, occurrence and examination of cracks, factors affecting the cracking, and environmental factors for corrective action. *EPRI Project Manager: C. E. Shoemaker*

PLANNING AND EVALUATION

The EPRI Regional Systems

P-1950-SR Special Report; $12.50

This report presents generation supply and system load data representing the characteristics of six U.S. regions as currently projected for 1990. It discusses the assumptions, information sources, and methodology used to compile the systems; possible applications; supply and load characteristics of each regional system; and ongoing and potential development to meet users' needs. A user's guide describes the computer tape file organization and content for each of the three major data sections. *EPRI Project Manager: J. J. Mulvaney*

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

NONPROFIT ORGANIZATION
U.S. POSTAGE
PAID
PERMIT NUMBER 7577
SAN FRANCISCO, CALIFORNIA

EPRI

ADDRESS CORRECTION REQUESTED

November 1981