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Cover: A representative sampling of projects
reveals the nature, scope, and direction of
EPRI's R&D program.

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The Need To Understand

There is a tendency among men and women in highly technical professions to feel that their work is something to be shared only with their peers. Indisputably, it is easier to communicate about one's work with those who have the technical knowledge to appreciate it, to contribute to it, or to apply it. This is a potential trap. Technical methodologies and findings themselves can seem tangible, even without being applied. But understanding their purpose goes well beyond a knowledge of facts alone. Furthermore, the audience that must ultimately understand is far wider than any constellation of technical peer groups.

Nowhere is this more important than in electric utility R&D, where programs in so many fields are maturing simultaneously. In particular, several new technologies will soon require heavy commitments if utilities are to have a broader base of fuel supply in the future. Floyd Culler emphasizes this point and its implications in his own message in these pages.

Having a full understanding of what EPRI is doing—why as well as how—is now urgent. One reason, for the utilities themselves, is the need to make choices of priority, not only between directly competing options but also among unrelated options when several are desirable but budgets cannot accommodate full demonstration of all of them. Another reason is to help others appreciate the bases of our priority choices so that continued efforts inside and outside the R&D community may be convergent, not divergent. (Those others include utility customers, regulatory bodies, and the executive and legislative branches of government.)

The times call for communications of a new sort and in new directions. The scale of energy use is such that even a modest percentage of change is enormous in megawatthours. The complexity of energy technology is such that investments are sobering in both size and risk, requiring wide sharing by government, manufacturers, and utilities over long periods of time. It follows that whatever EPRI undertakes is far-reaching in its effect on U.S. industry, labor, capital, markets, and consumption—in short, on our society and its economy.

The National Association of Regulatory Utility Commissioners (NARUC) recognized this a little over a year ago. It requested EPRI to present annual progress reports to the five regional NARUC affiliates, informing commissioners and their staffs on research results, on work under way, and planned activities. NARUC also asked EPRI to consider whether its own staff members might provide insight on specific technologies or research programs when so asked by individual state commissions.

This NARUC request speaks directly to my point about the need for understanding that goes beyond technical knowledge to the need for understanding by constituencies outside the technical community. Regulatory bodies are the forum in

which the perceptions of energy technologists, government, and the public meet, the forum in which they conflict or coincide, diverge or converge.

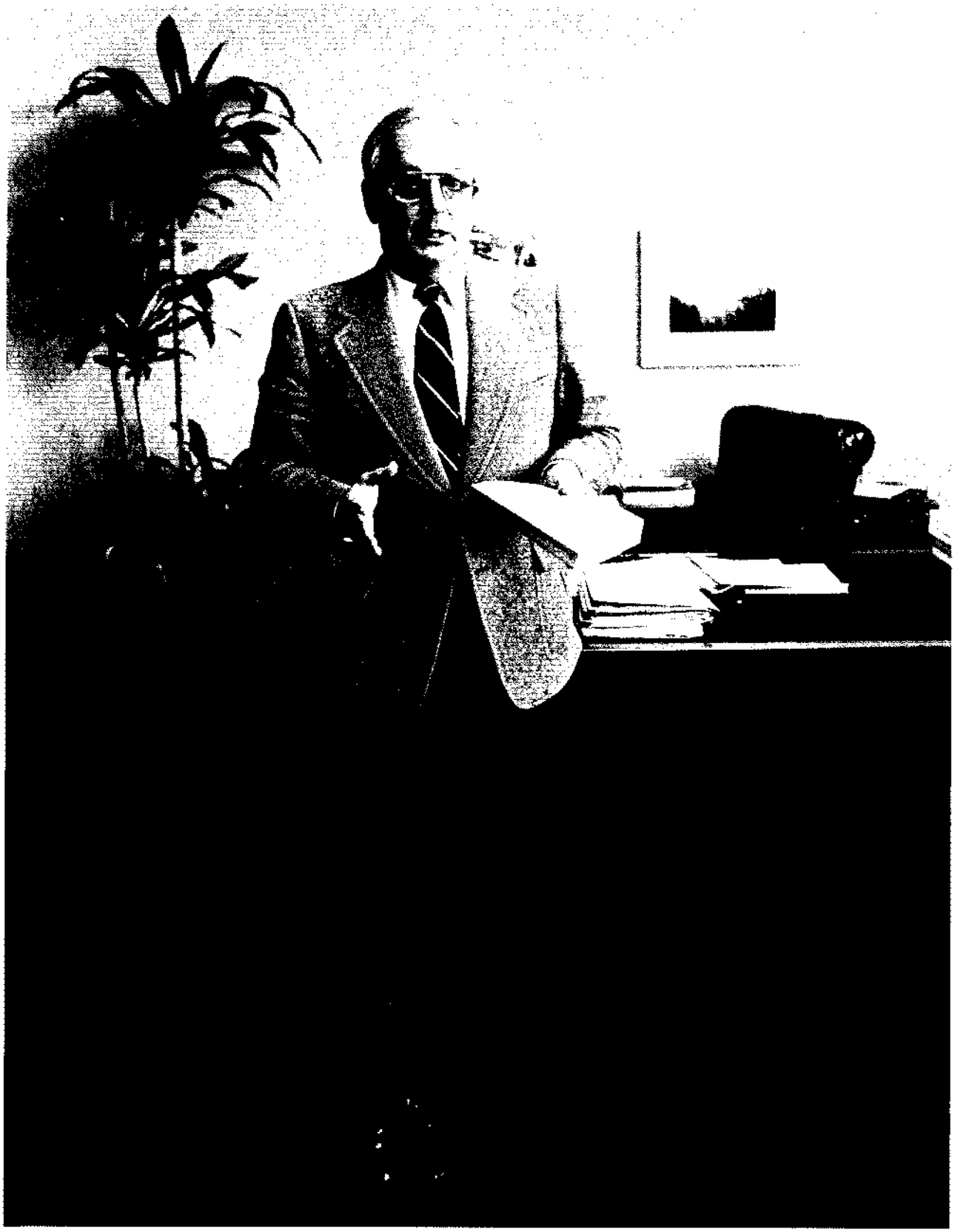
EPRI has agreed to the NARUC request. That agreement, with the concurrence of the Board of Directors, is in the form of a statement of background and guidelines for communication. In my opinion its spirit is unconditional. If there is any condition, it is only that EPRI staff members not become participants in formal adversary proceedings. Such participation would threaten the objectivity and detachment of EPRI research, and it would almost certainly lessen the Institute's credibility with one or the other party to the detriment of full or true understanding.

I have outlined the background and progress of this innovative communication program to the chief executive officers of all EPRI member utilities, and I welcome this particular issue of the *EPRI Journal* as a forum in which to emphasize my own thoughts about the fortuitous timing of NARUC's interest. The following pages summarize many current EPRI research projects, largely in terms of why they are important rather than simply how they are being conducted or how a process works. This year-end review is itself a timely step in communication.

Understanding the course of EPRI's research on behalf of the electric utility industry is only partly a matter of understanding the technologies themselves. It is also a matter of understanding why research that ''fails'' is a success if it forestalls further expense on something that is ill-timed or infeasible; why a mix of technical options is indispensable for even one utility, and certainly for the entire industry with its widely varying patterns of fuel availability, population and industrial density, weather, and the like; why the demand for reliability must not stifle innovation, but why also it imposes lengthy time requirements for new ideas to be proved before being put to practice; and why capital and operating economies demand thorough and methodical evaluations that extend beyond any technology and encompass support industry capabilities (material, transportation, labor) and market potential.

There is no substitute for a utility's individual articulation of these—or other—bases for the R&D it underwrites. But it is also appropriate that EPRI elaborate and clarify its purposes, its progress, and its promise for ratepayers to the regulatory representatives of those ratepayers.

Frank M. Warren, Chairman
EPRI Board of Directors
and
Chairman and Chief Executive Officer
Portland General Electric Co.



Challenges of the Next Decade

by Floyd Culler

Paramount is the need to develop new fuels and new techniques—obtaining and converting fuels by processes that meet present and anticipated regulatory requirements.

Six years ago the private and public electric utilities established EPRI to conduct R&D on their behalf and in the public interest. This research and development will provide new technology to produce and deliver electricity from a variety of energy resources. The new fuels, plants, and methods of delivery and storage must be environmentally benign and of minimum risk to human health. These objectives must be achievable at the lowest possible cost, together with the careful development of methods to improve efficiency and to reduce waste by conservation.

During my first year at EPRI, I have been impressed with how well these broad objectives are being met. I have been pleased with the diversity of the advisory structure through which requirements are defined, guidance is sought, and understanding is obtained. Most of all, I have been delighted with the ability, intelligence, and spirit of the staff.

The EPRI R&D programs are beginning to produce information and technology of significant, practical, commercial value. Five years of research and small-scale experimental effort have produced processes and systems that are ready for pilot-plant or demonstration-scale tests. This transition from the laboratory to large-scale practical systems, through pilot plants and demonstrations, should now be undertaken as rapidly as possible in several areas to derive benefit from the foundation of earlier government and privately sponsored development.

The most difficult challenge for EPRI and the utilities during the next few years will be that of consolidating the elements of EPRI science and engineering, equipment performance, regulatory requirements, resource availability, and costs into working systems.

Of the many and diverse problems being studied by EPRI, the R&D necessary to produce and deliver an adequate supply of electricity with environmental

Floyd Culler is president of EPRI.

compatability is of paramount importance and is receiving the most attention.

Processes for obtaining and converting fuel are being developed to meet present and anticipated regulatory requirements. From 40 to 50% of EPRI's R&D is motivated by concerns for the environment and human health. The first processes chosen for commercial-scale tests are improved methods of cleaning the flue gas of particulates, oxides of sulfur and nitrogen, and other potentially deleterious products resulting from coal combustion.

An overall strategy

Before proceeding with a description of the sets of options (and constraints) that may be potential solutions to problems of supplying electricity in the future, I would like to describe the EPRI mission, set a few ground rules, and sketch the outlines of a broad plan.

We are planning for the technology to permit power supply options for an expanding population and economy in the United States. For the year 2000 we are using a population estimate of approximately 260 million, with a work force of 124 million. As a midrange guess (for quite valid economic reasons), we assume a steady but not spectacular rise in the GNP: 3% a year through 2000, and 2% through 2030. Although the energy wars are really being fought over the issue of how much energy is needed for such a modest expansion in the economy (some believe that it is very desirable to almost stop increases in energy use and limit overall growth rate), our predictions are based on what we think is a prudent view of energy requirements in the future. Thus, we continue to think that total energy use will increase with population, employment, and the GNP, albeit at a somewhat lower rate than in the past.

Presently, we are basing our future R&D program on estimates that predict a total U.S. energy consumption of 130 quads in the year 2000 (less than twice 1978 consumption). Electricity production from domestically abundant coal and nuclear fuels will replace other fuels in existing and in new plants. A prudent planning level for the year 2000's electric generating capacity is about 1250–1300 GW, with a possible generation of about 6100 TWh, about three times that generated in 1978.

The focus of EPRI's R&D will be about 45% on immediate problems, about 45% on systems for the intermediate term (until 2000), and about 10% on promising new technology for the long term (beyond 2000).

New and replacement generating capacity will most certainly use coal and nuclear power as primary energy sources. We assume that nuclear capacity will reach 350–400 GW in the year 2000 because of lower costs and an otherwise sizable burden on coal production. Of course, the extent of the use of nuclear power is not at all certain at this time because of various issues and problems of public acceptance.

Now and in the future, energy conservation and the efficient use of fuel will reduce potential energy consumption. Our estimates for total energy and electricity use assume that conservation in all sectors will reduce the consumption potential by about 15–20%. To make this estimate a reality, our programs in conservation and efficiency will need to be expanded as rapidly as sound ideas can be developed.

Supply—options and choices

The processes and fuels that have been chosen for development must be reviewed each year. So too must the selection of the technical bases for electricity generation be reviewed as the understanding of new techniques broadens. Since we think that coal and nuclear power will provide 80–85% of the electricity in the year 2000 and electricity will provide 40–45% of all energy needs, it is essential to do all we can to ensure that the nuclear option is available and to provide clean and safe systems for using coal.

Coal Our coal program is concentrated on the following areas, with the emphasis roughly corresponding to the order in which progress is described.

Advanced flue gas cleaning is now going into the large pilot-scale stage.

Clean combustion processes, such as atmospheric and pressurized fluidized beds, are about ready for tests.

Coal conversion to gas (and perhaps heavy residual crude oil), coupled with combustion turbines in a binary cycle, offers the possibility of improving efficiency in an environmentally benign manner. Binary-cycle technology is now available for testing.

In a somewhat later timeframe, using storable coal-derived liquid fuels in combustion turbine–binary-cycle plants will provide a stable, domestically available clean fuel for the utilities. (As of today, however, the liquids seem likely to be more expensive than gas from coal.)

Nuclear Power Development for nuclear power is concentrated on improving efficiency and performance in PWRs. We will be devoting increased attention to the back-end of the nuclear fuel cycle and to waste management and disposal. We will continue to support strongly the national efforts to provide a demonstration of a successful breeder option by the mid-1990s. Although this important program is stalled in the United States, it is proceeding nicely abroad. The breeder—almost certainly the LMFBR—will provide a long-term energy resource.

Advanced Systems So too, of course, could solar energy, but at higher costs, in smaller practical quantities, and on a time-variant base. We are now supporting development of solar heating, cooling, and hot water, in conjunction with heat pumps and energy storage. In addition, we are looking at each reasonable process for converting the sun's energy to electricity—photovoltaic cells, thermophotovoltaic devices, and solar collectors with Brayton and Rankine cycles and various heat transfer media.

The fuel cell program is very well

advanced; a 4.8 MW (e) pilot plant is now being constructed. New cell technology will make the more developed phosphoric acid cells economically attractive, hopefully in the early 1980s. A utility user group is now forming in order to provide support for commercialization.

We also support geothermal generating systems, battery development and testing, and other energy storage systems. The potential of using wood, wastes, and cultured biomass materials is receiving attention.

The potential of fusion energy is improving as the confidence in demonstrating scientific feasibility increases, as it has this year. Our program, though modest compared with that of the federal government, is complementary and provides a window through which we continue to observe this exciting long-term potential.

Electrical Systems Work to produce more effective electric generating, power conditioning, transmission and distribution equipment and systems is now producing the most widely recognized benefits of all EPRI's research. This R&D is practical, useful in both short and long term, and is characterized by real imagination and usefulness. We are improving these systems at a pace set by the needs and the availability of good ideas to solve them.

Demand—new perspectives

We will continue to expand and to explore the useful approaches to balanced demand and conservation measures. We will assist the utilities in making use of effective conservation practice when our technology can be of help. New approaches, such as time-of-day pricing, rate design, active demand management, and other programs of broad interest will become increasingly important in our R&D.

Programs and studies to improve the accuracy of projections for electricity and energy needs for the future will be maintained. Models are, of course, now widely used; we will continue to provide methods for monitored cross checking of model effectiveness.

Environment and health

Approximately half of the R&D programs at EPRI have been established to protect the environment and human health. Most of the large funding is going into developing the technology to provide for safe energy systems. But the R&D in assessing environmental effects, on measuring basic responses to potentially deleterious effluents, and in providing means for their control is and will continue to be one of the most important of EPRI's programs.

EPRI is now recognized as a major contributor to this broad field. We are sure that our work will help protect people and other living things from any possible effects of oxides of sulfur and nitrogen, particulates, and toxic materials in soil and water. We are leading in support of work on the effect of electric fields on living systems. The informed resolution of contentious questions of radiation exposure and the exploration of long-term problems, such as carbon dioxide and dust concentrations in the atmosphere, will serve the public interest in the most fundamental way and at the same time allow utilities to meet their obligation to supply electricity.

The 1980s

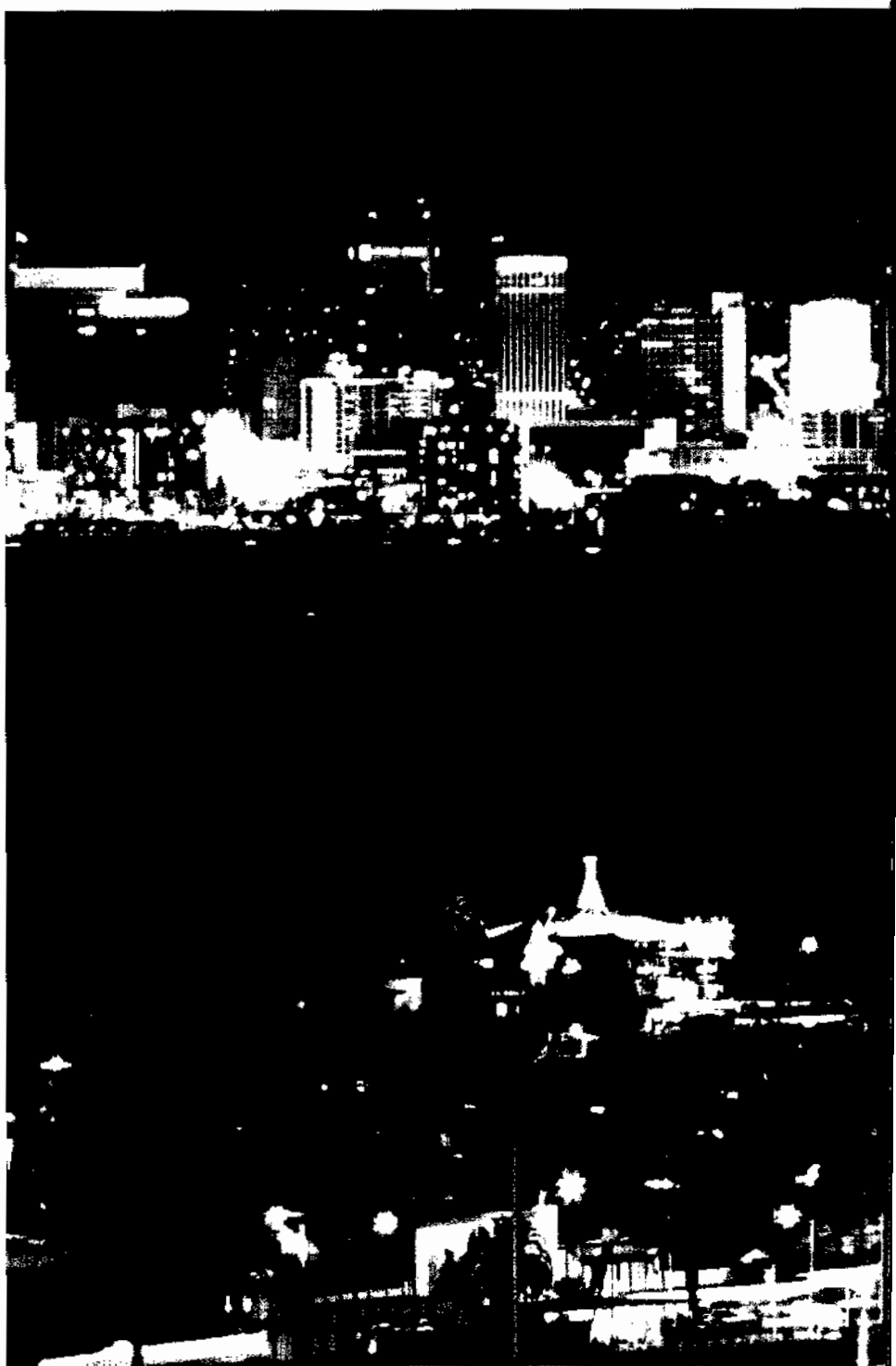
There are many subjects not covered in this short essay. My omission does not diminish their importance in the utilities' R&D program. But we do have a comprehensive program and the plans to make it possible for the utility industry, public and private, to meet the demands of any transition in generating methods and fuels. An effective advisory structure and staff are working in harmony to move new developments from laboratory to use. With these, it will be possible to move intelligently and prudently into the next 10 years of test and plant-scale application.

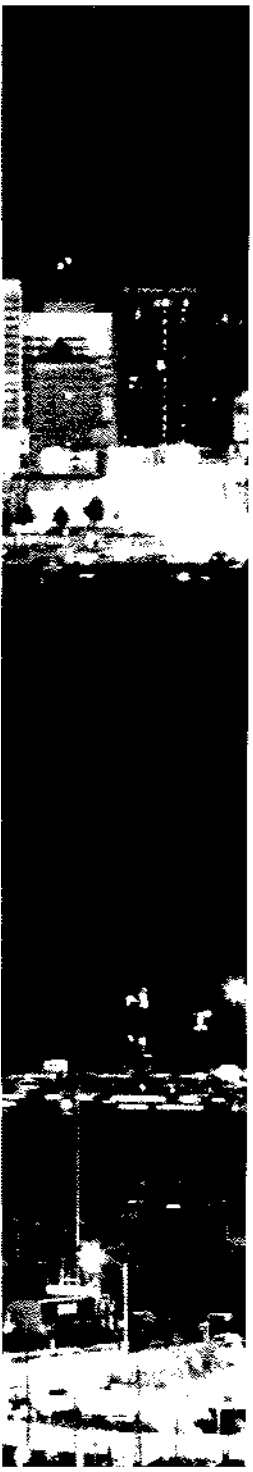
Scanning the Research Agenda

The universe of EPRI's work extends to 1000 R&D projects. Displayed are several areas of research activity that encompass 30 representative probes into the future of electric energy technology.

Demand and supply

The two main factors that shape utility planning are demand and supply—projected consumer demand for electricity and anticipated available supply of fuels to generate that electricity. EPRI continues to update and refine its demand and supply forecasting models to serve as a guide for utilities in their long-range planning. The demand 79 and supply 79 forecasts have been extended to the year 2030. The new demand model projects electricity, fuel oil, and natural gas consumption in the commercial and residential sectors and energy use for transportation. Total electricity demand is foreseen as growing slightly less than that forecast in *Demand 77.* The supply 79 model projects production levels and price for major fuel alternatives. Coal production capability is placed at about the same levels as those forecast in *Supply 77,* with prices slightly adjusted. Coal production for 1985 is expected to be about 1 billion tons at a price of around $17.50 per ton (in 1976 dollars). (Demand: RP662, RP757, RP1098; Supply: RP950, RP952, RP1009, RP1430)





Planning for uncertainty

A computer model has been developed that estimates the range of least-cost planning reserve margins under conditions of uncertain customer demand. Taking into account outage costs, the model demonstrated that overcapacity is less costly to consumers than undercapacity. The project is being extended to study the effect of a variety of uncertainties on technology mix, that is, the various possible combinations of nuclear and fossil-fired generation, as well as load management and new technologies, such as fuel cells. Sensitivity analyses in the first phase of the project indicated that decisions on technology mix may have a significant effect on consumer costs. Various uncertainties, such as varying load shape and the escalation of capital and fuel costs, are now being examined with the methodology developed earlier. (RP1107)

"This model for planning an uncertain future is elegant and broad in scope. It is a marvelous black box, but because it takes into account so many variables and is still quite new, we are using it with caution and a certain amount of skepticism."

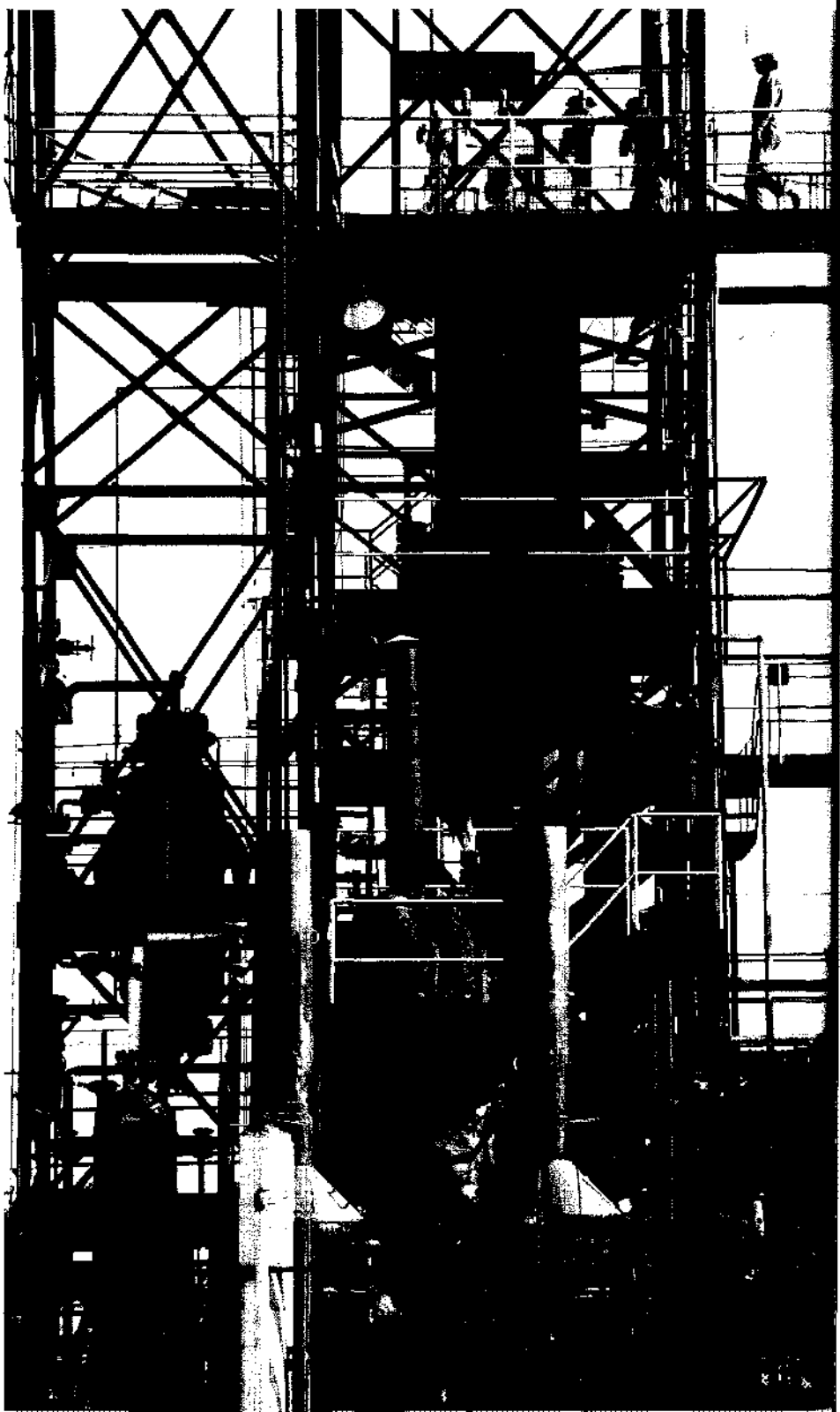
Jack Prince
Manager of Planning, Wisconsin Electric Power Co.

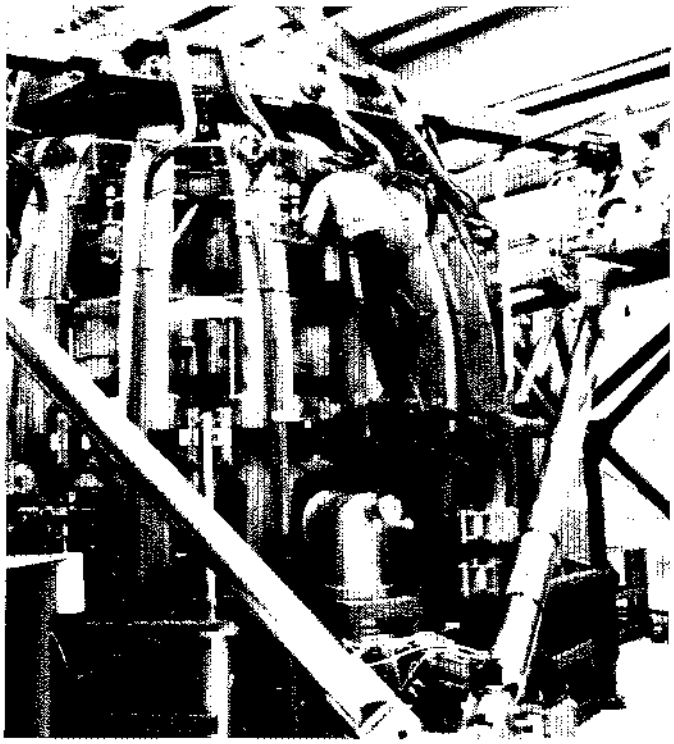
Coal gasification for combined cycles

Integration of a coal gasifier with a combined-cycle generating unit holds high promise for better use of coal in electric power production, perhaps by the late 1980s. Among the objectives are higher thermal efficiency, lower emissions, and high system reliability for both cycling and baseload service. Texaco, Inc., Southern California Edison Co., and EPRI are planning a $28 million effort to design a 100-MW demonstration plant, with construction scheduled to begin by 1981 and operation by 1984. A key item is Texaco's single-stage, pressurized coal gasification process. Fed with a coal-water slurry, it is simple and flexible, with no moving parts; and a short residence time for the reactants permits the rapid response needed in load-following service. The high-temperature operation avoids the formation of tar by-products. (RP1459)

"Demonstration will be the ultimate proof, of course. But system-modeling studies—begun by Philadelphia Electric Co. and carried on by Fluor Engineers and Constructors and Westinghouse Electric Corp.—give this project a design edge in matters of economy, control, and reliability, as well as in the basic compatibility of the gasifier and combined-cycle units."

Charles F. Mengers
Director, Research and Testing Division, Philadelphia Electric Co.; Member, EPAS Program Integration and Evaluation Advisory Committee, EPRI





Nuclear fusion

Even though net energy production from nuclear fusion has yet to be achieved, efforts are under way to establish plant and process characteristics most suitable for commercial electric power production. A major experiment is the Doublet III reactor, designed by General Atomic Co. with $2.3 million in EPRI support and built under DOE auspices. The Doublet program is now the basis for design refinements to improve fusion reactor availability and reliability. One EPRI project has addressed in situ replacement of the first wall by vapor deposition of silicon carbide, thus avoiding long periodic outages for reactor dismantling and reassembly. Another project is examining RF-driven steady-state reactor operation, thus avoiding the severe thermal stresses that result from pulsed operation. (RP323)

Photo by *Newsday*

Solar heating and cooling

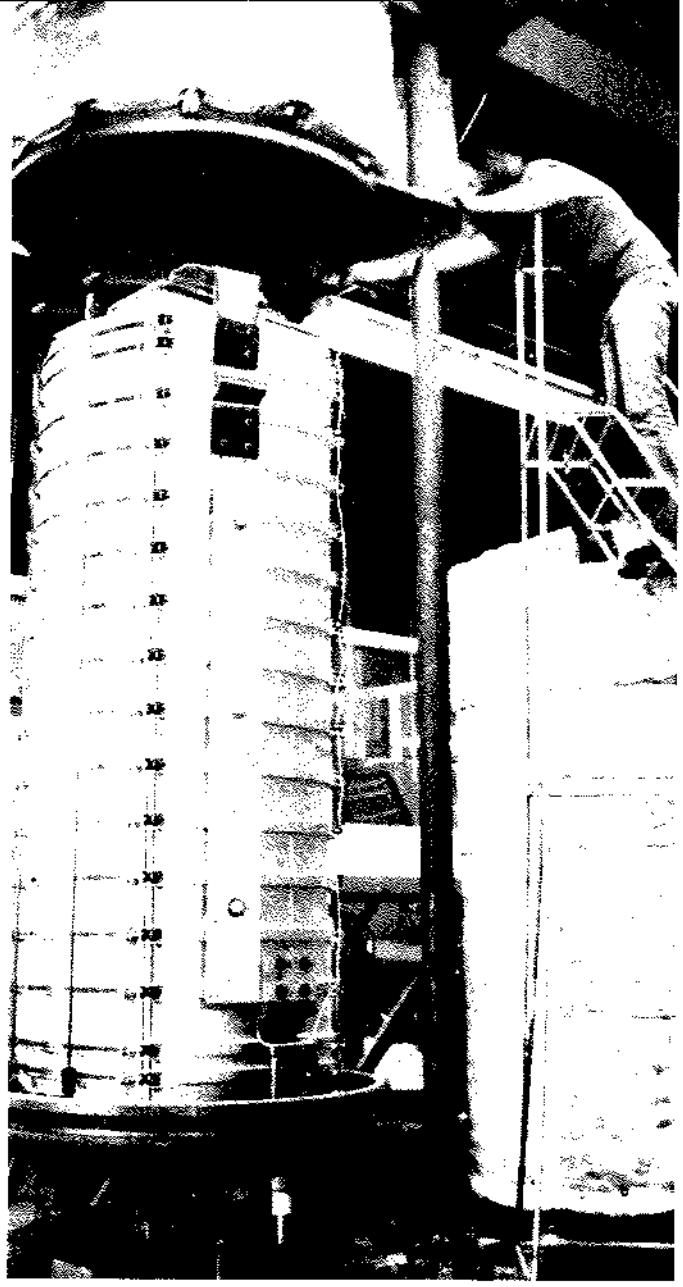
Solar energy will increasingly be used for space heating and hot water, and perhaps for cooling, too. But how should solar systems be designed in order to minimize the amount and cost of electric generating capacity that will still be needed for heating and cooling during the most extreme weather? The lifestyles of 10 Long Island and Albuquerque families in their specially designed homes will lead to the answers. Their solar collectors, energy storage tanks, heat pumps, and air conditioning units are being monitored—along with the weather—for two years, providing data that enable the simulation of more than 100 other system and weather combinations. In addition, this $3 million project will refine a computer program for selecting optimal solar home systems almost anywhere in the United States. (RP549)

Liquid fuel from coal

Liquefied coal fuels are under accelerated development to meet several utility criteria: a substitute for petroleum if policy or price drives it off the market, a more consistent fuel quality than raw coal, reduced emissions, ease of transportation and storage, and suitability for use in oil- and gas-fired boilers, as well as in combustion turbines, combined cycles, and fuel cell plants. But how well does a coal liquid burn under operating conditions? Development of the solvent-refined coal process has been carried to the pilot plant stage by DOE, and 4500 barrels of SRC-II liquid was tested last summer in a Consolidated Edison Co. boiler in New York City. Early data from EPRI's test contractor, KVB, Inc., indicate good performance, with emission of both NO_x and particulates at lower levels than anticipated. (RP1412)

Fluidized-bed combustion

For acceptable performance, coal-fired boiler and emission control designs are closely tied to the combustion properties of specific coals and to their ash, nitrogen, and sulfur content. Fluidized-bed combustion may be a way to reduce these dependencies and achieve a nearly standard boiler design that requires only fly ash removal from the flue gas. Fluidized by forced air, the burning coal and limestone yield heat at temperatures low enough to suppress NO_x formation and allow sulfur capture by the limestone. Babcock & Wilcox Co. built and is now operating a fully instrumented fluidized-bed unit, 6 × 6 ft (1.8 × 1.8 m) in section, 50 ft (15 m) high. It will be used through 1980 to develop key scale-up data needed for a utility demonstration boiler. (RP718)



"Fluidized-bed combustion is a way to burn high-ash coal without fouling a boiler and having to derate its capacity. We're designing a 200-MW demonstration plant for the TVA system, and the B&W 6 × 6 ft unit is generating the kind of reproducible performance data we need."

Sidney Maylor
Senior Engineer, Engineering and Construction Dept., Boston Edison Co., Member, Energy Management and Utilization Technology Task Force, and Chairman, Fuel Cells and Chemical Energy Conversion Technology Program Committee, EPRI

Electrochemical energy conversion

The ideal generating unit is efficient over a wide range of loads; responds quickly to transients and load changes; is cost-effective to build and operate, regardless of size; and is so clean and quiet you don't know it's there. The best bet for meeting these criteria is a fuel cell power plant, and cells for a 4.5-MW demonstration unit are now being manufactured by United Technologies Corp. When installed on the Consolidated Edison Co. system in New York City, the module will undergo 6700 hours of tests. By 1982 the $60 million project (including an EPRI share of $11 million) should be conclusive in qualifying electrochemical energy conversion for the utility market. (RP842)

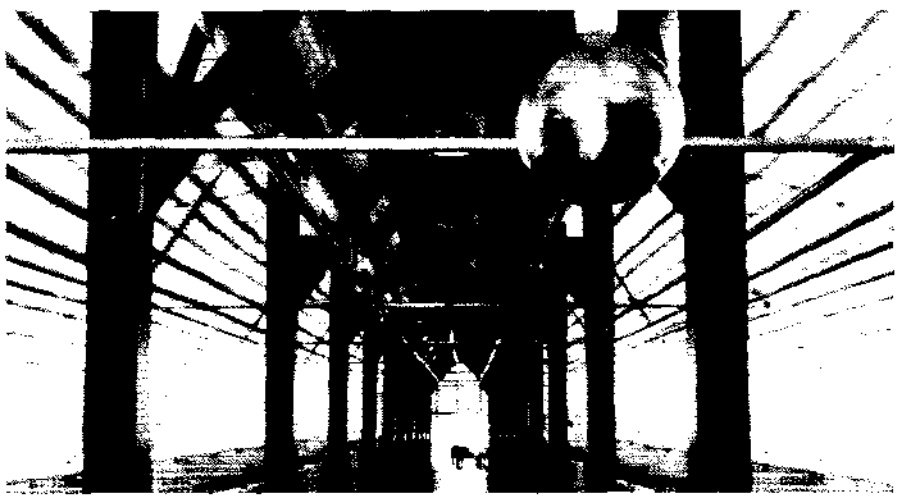
"When I tell people that the first-generation fuel cell plant efficiency is 39%, they ask, 'Is that all?' They forget that the first steam turbines were probably below 20%! Fuel cells must be installed on several utility systems to show what they can really do. If they can be sited in New York City, they can be sited anywhere."

Regional sulfate monitoring

Fifty-four ground monitoring stations and five instrumented aircraft have collected air samples over a 16-month period ending last October to identify the sources, concentration, and transport characteristics of sulfates and other significant air pollutants in the northeastern United States. The mass of data collected in the three-year, $6 million sulfate regional experiment (SURE), which is being analyzed and used for improving long-range transport models, is expected to yield "the most complete and best data available on regional air quality, including the emissions inventory," according to Ralph Perhac, program manager. A final report of the study is anticipated in early 1980. SURE data will provide a significantly improved scientific basis for regulatory consideration in setting standards for airborne pollutants. (RP862)

"Animal toxicology studies are a demonstrated method for identifying those products of fossil fuel combustion that could be harmful to human health. Data so gathered, along with evidence from human exposure studies and epidemiologic investigations, should lead to rational standards for protecting human health and thus allow utilities to supply electricity at reasonable cost."

Charles Goodman
Manager, Air, Water, and Thermal Sciences Program, Southern Company Services, Inc.; Chairman, Task Force on the Environment, EPRI



Animal toxicology studies

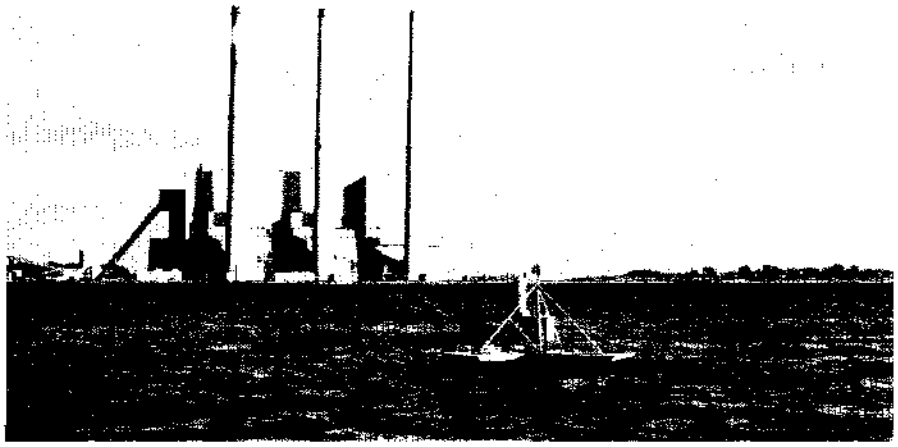
Several animal toxicology studies, under way for nearly two years, are aimed at identifying emissions from fossil fuel combustion that could cause adverse health effects from either acute or chronic exposure. Scientists at the Massachusetts Institute of Technology are simulating various combustion conditions in model furnaces and exposing guinea pigs to the gaseous emissions. All the animal studies are supervised by physicians and veterinarians to ensure compliance with humane practices set by federal guidelines. At the University of California at Irvine, investigators are studying the effects of mixed and aged atmospheres on laboratory animals and duplicating the effects on growing, developing lungs. A team of scientists—biochemists, pathologists, and specialists in infectious diseases—at the National Primate Center, University of California at Davis, is observing the effects on primates of continuous long-term exposure to air pollutants. (RP1112)

Clinical studies

Several major studies are under way in a $16 million effort to determine the human health effects of the significant air pollutants. Chief among the efforts is the Six Cities' study conducted by the Harvard School of Public Health and co-funded by the National Institute of Environmental Health Sciences. The largest ongoing air pollution–epidemiologic investigation in the United States, this nine-year study is designed to measure the levels of sulfur dioxide, sulfates, nitrogen oxides, and respirable particulates and to determine their effects on the health of adults and children. Correlations will be made between pollutant levels and pulmonary function, as well as between pollutant levels and variations in such illnesses as chronic bronchitis, asthma, and respiratory infection. The results could have implications for regulatory control of specific pollutants. (RP1001)

"Among the several aspects that make this an especially important study of the potential health effects of air pollution are the high caliber of the investigators and the thoroughness of the study design. The results should provide a scientifically sound data base for evaluation of effects."

David Daugherty
Chief of Research Services, Division of Energy Research, TVA; Member, Task Force on the Environment, EPRI



Cooling system effects

An extensive computerized data base on power plant cooling system effects—compiled from unpublished industry reports, as well as from information published in journals, books, and government documents—has been developed and is available for use. Ecosystem models are also being designed to assess the effects of single-plant cooling systems on lakes, rivers, estuaries, and marine populations and the effects of several power plants on a single body of water. The models will be tested by application to representative plant sites, including the lower Hudson River and Cayuga Lake in New York and Cape Cod Bay in Massachusetts. Other work involves a comprehensive review and evaluation of the ecological aspects of cooling impoundments and power plant operations. (RP573, RP876, RP877, RP878, RP880)

"These studies should provide a clearer insight into the effects of power plant cooling systems on aquatic ecosystems. This knowledge will in turn enable us to predict more accurately what these effects will be at new and proposed sites, thus allowing us to use more wisely both fresh and marine waters for power plant cooling purposes."

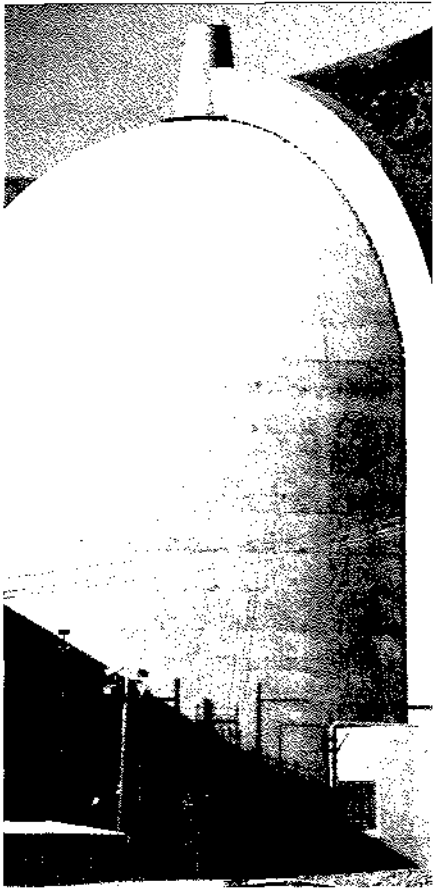
Frank Schlicht
Principal Scientist, Environmental Protection Dept., Houston Lighting & Power Company; Vice Chairman, Task Force on the Environment, EPRI

High-voltage effects

A number of investigations have been launched to determine the effects on plant and animal life of exposure to high-voltage electromagnetic fields, especially those occurring under and around utility transmission lines. Studies have been designed to measure effects on large animals, mice, chick embryos, honeybees, and plants and to assess the possible effects on humans. Some results so far: the threshold for effects on plants with pointed leaves has been found to be 22 kV/m, but no effect on plants with round leaves has been found up to 80 kV/m; exposures of small laboratory animals to 100 kV/m for 30 days, 20 hours per day, caused no adverse effects. The second generation of a population of Hanford miniature swine is being bred in special exposure chambers constructed for the large-animal phase of the program at Battelle, Pacific Northwest Laboratories in Richland, Washington, with both conception and birth taking place within the experimental electric fields. The exposures do not cause pain or grossly observable effects on the animals. (RP129, RP381, RP679, RP799, RP934, RP1064)

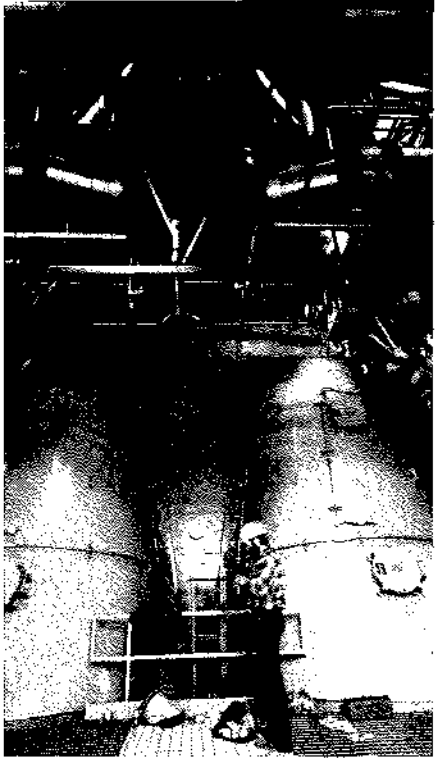
"We live in a world of increasingly higher voltages in transmission lines. So far, research has shown no adverse effects, but it is important to continue to investigate the possibility of health effects so as to provide adequate protection for the general public as well as utility employees."

Harrison Mehn, MD
Medical Director, Commonwealth Edison Co. Member, Task Force on the Environment, EPRI



Probabilistics

There are a number of potential events that have a very small probability of occurring in a nuclear power plant. To obtain some realistic estimate of the likelihood of their occurrence and the consequences for use in safety analysis, EPRI is supporting a number of projects to help answer licensing questions. Interest is in two areas: the probabilities of occurrence of an accident exceeding a given magnitude and the probabilities of the out-of-plant consequences exceeding a specified level. EPRI has made contributions in estimating the likelihood of an automatic reactor safety system's failure to operate as designed when called upon to react to a minor yet expectable perturbation of steady-state plant operation (the so-called anticipated transient without scram syndrome). Other work has focused on the modeling of operating uncertainties and the analysis of multiple uncertainties on safety analysis. (RP767, RP1233)



Radiation control

As more operating nuclear power plants move from their startup years into steady state mode, and the average background radiation also increases toward a steady state, EPRI's program on radiation control becomes more significant in affecting plant availability and maintainability. Plant monitoring and sampling projects have demonstrated that activated corrosion products (in particular, two cobalt isotopes) are the primary sources of radiation fields that persist after shutdown. Techniques for controlling these fields through chemistry control during power operation and during shutdown procedures are being tested at a number of PWR plants and are lending significant insight into corrosion-product transport control. In BWRs, efforts are under way to identify a suitable low-cobalt alloy to be used in control blade assemblies, a principal source of cobalt-60. Decontamination reagents have been identified that reduce radiation fields on sample BWR bypass lines by an 8–10 factor in a few hours. (RP819, RP825, RP828, RP966, RP1329, RP1331, RP1445)

"As plants age, the long-term trend is toward higher irradiation dose rates at individual components, while the corresponding long-term trend for regulation is for lower total absorbed doses. These two trends are inconsistent and something has to be done. EPRI has defined this problem, has served usefully in alerting the industry, and has obtained a fairly good quantification of what the problem is likely to be."

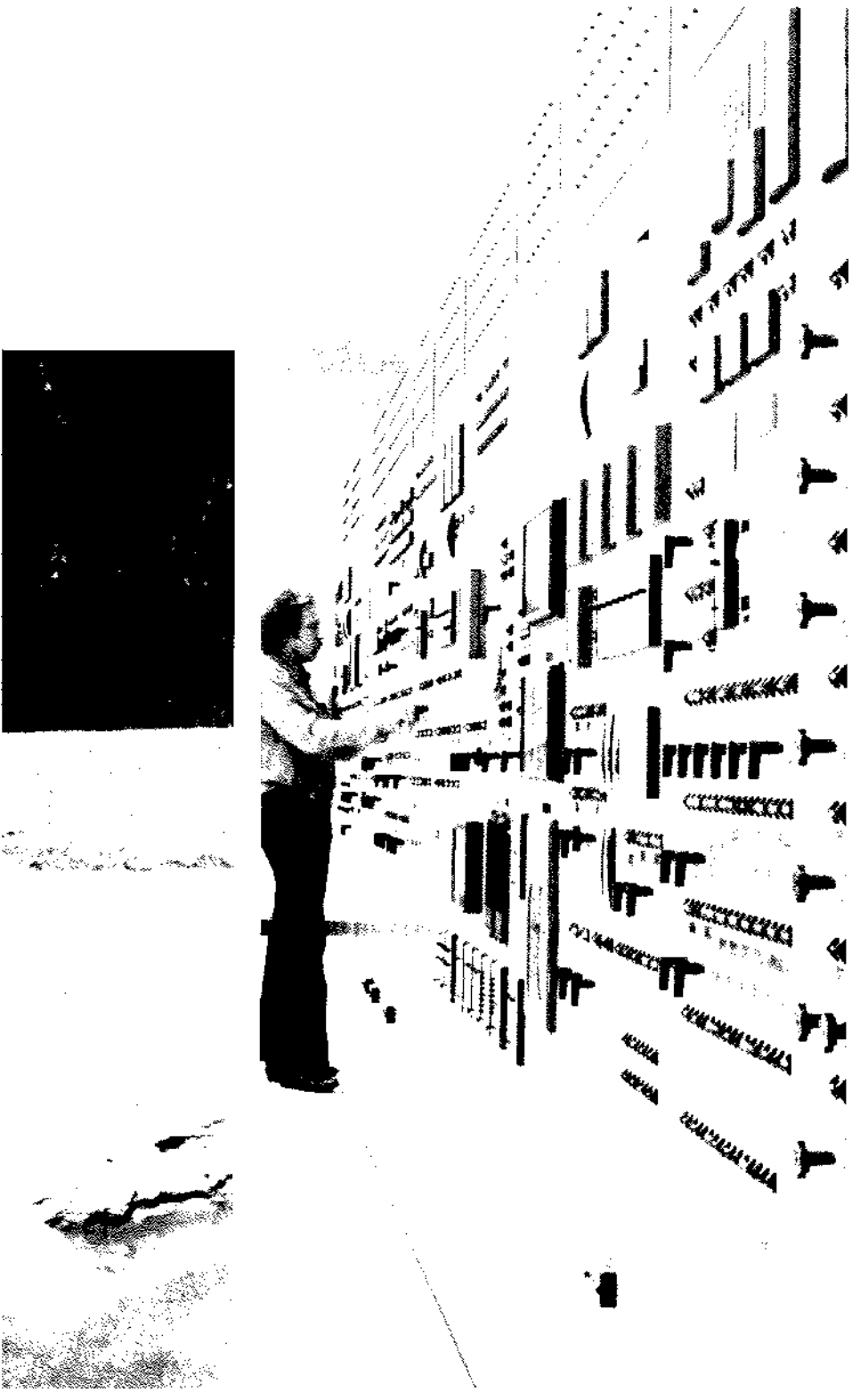
Steve Rosen
Manager, Nuclear Engineering Dept., Boston Edison Co.; Member, Engineering and Operations Task Force, EPRI

Advanced SO_2 scrubber

Flue gas desulfurization will remain the dominant means for control of SO_2 emissions from power plants during the next 10–15 years, an interval likely to see 200,000 MW of new coal-fired capacity requiring scrubbers. The clear need is for better sulfur removal efficiency, diminished water use, improved reliability, reduced capital and maintenance costs, and attention to the volume and character of scrubber wastes. One attractive technology is the Chiyoda Thoroughbred 121 process, which yields calcium sulfate (instead of calcium sulfite sludge). Practically pure gypsum, this material dewaters rapidly and can be stacked in a limited area, and it may have by-product value in the wallboard and soil conditioner markets. A Chiyoda scrubber is now under EPRI-sponsored evaluation at 20-MW scale at the Scholz station of Gulf Power Co. (RP536).

"This scrubber shows promise for economy because its design and operation are simpler than other processes—no forced-oxidation and other satellite pumps and tanks—and because the waste is stable for easy handling."

Alex Kaiser
Director, Power Engineering Dept., Tampa Electric Co., Member, Fossil Fuel Power Plants Task Force, and Chairman, Desulfurization Processes Program Committee. EPRI



Human factors

Because of the extremely conservative safety requirements of nuclear power plants, a program to improve the human engineering of power plant control rooms was initiated in EPRI's Nuclear Power Division. However, the program is now being expanded to embrace many additional aspects of the man-machine interface in utility applications beyond nuclear plants. An outline for such a broader program, which is being drafted, includes application of human engineering to power plant operators, maintenance crews, pool and system dispatch center operators, substation operators, linemen and troublemen, and support personnel; those involved in design and specification of systems, components, tools, and support equipment; and those training power plant personnel. Expected benefits of such a program include increased reliability of power supply to customers, improved economics, increased personnel and system safety, and improved personnel morale. (RP501, RP769, RP1126, RP1354, RP1396)

"The human factors research effort by EPRI that has developed over the past few years has the potential to save substantial outage time for electric generating stations. Studies have shown that about 25% of forced outages involve the man-machine interface. There is a broad base of support in the utility industry for this work, and coupled with the effort of the EPRI staff, it will result in a carefully articulated program in human factors research. Implementation of what is learned as an outcome of this research should be a significant contribution to improved power plant availability in future years."

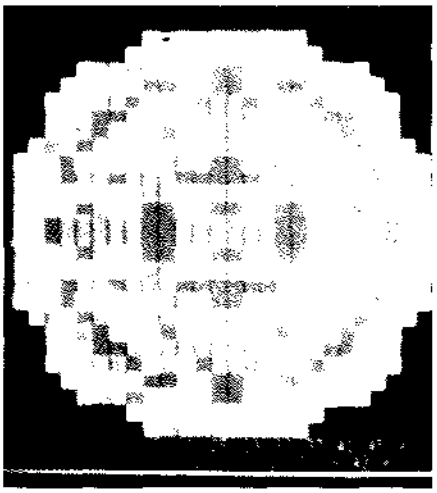
John Beck
Vice President, Vermont Yankee Nuclear Power Corp.; Chairman, Engineering and Operations Task Force, EPRI

Computer code development

In the past few years, utilities have found increasing need for the analytic capability to perform safety, fuel management, and operations support analysis. EPRI has therefore centered a major effort on developing computer codes to meet these needs. This year a number of new codes reached the stage where they can be effectively used by the industry. Among these are RETRAN, a flexible tool for analyzing a variety of reactor plant transients; COBRA/3C–MIT and SIMULATE, which provide a three-dimensional capability for reactor core analysis (COBRA/3C–MIT handles core thermal-hydraulic analysis, and SIMULATE calculates power distributions for fuel management and operations support); MANAGE, an operations analysis code to examine multiyear strategies for utility generating systems; and the WAM family of codes for use in quantitative fault tree analysis. Recognizing the need for providing a mechanism to ensure that such codes get continuing maintenance and support, EPRI established the Electric Power Software Center in 1977. (RP227, RP298, RP710, RP811, RP885, RP889, RP1233)

Seismic tests

The initial phase of EPRI's seismic research concentrated on nonlinear soil-structure interaction from earthquake excitation. Cyclic excitation with explosives has shown that the rocking frequency of interest decreases with increases in the magnitude of excitation. This is due to the nonlinear changes in the adjacent soil properties, which tend to shift the rocking frequency away from higher-frequency components. The study also demonstrated that in certain instances, two-dimensional analysis gives conservative results when compared with realistic three-dimensional ones. Three-dimensional analysis was shown to be economically feasible, and such an option is being developed for the coming year. (RP810)



Fuel improvement

Although LWR fuel reliability is generally very good, it is achieved at the expense of some limitations on plant maneuverability and capacity. These are self-imposed to maintain an extremely low rate of fuel rod failures because there are some uncertainties about fuel behavior. These limitations reduced plant capacity in 1977 by an average of about 1% for PWRs and 3% for BWRs. The related cost of replacement power currently runs at about $100 million a year, and with more plants nearing completion, could rise to $400 million by 1985. The incentive to understand fuel behavior better and eliminate uncertainties is therefore tremendous. EPRI research in this area has already yielded important results on the phenomenon of pellet-cladding interaction and on the behavior of Zircaloy cladding under operating conditions. This and related work promises to significantly reduce capacity loss in PWRs and substantially reduce loss in BWRs shortly. (RP355, RP455, RP507, RP895, RP971, RP1026, RP1027)

"We have applied EPRI's improved fuel performance codes to our operating reactors. We use the codes to resolve safety issues and find we can achieve a significant reduction in the time and manpower necessary to carry out required analyses. In addition, direct cost savings have been significant in both safety-oriented codes and fuel management codes."

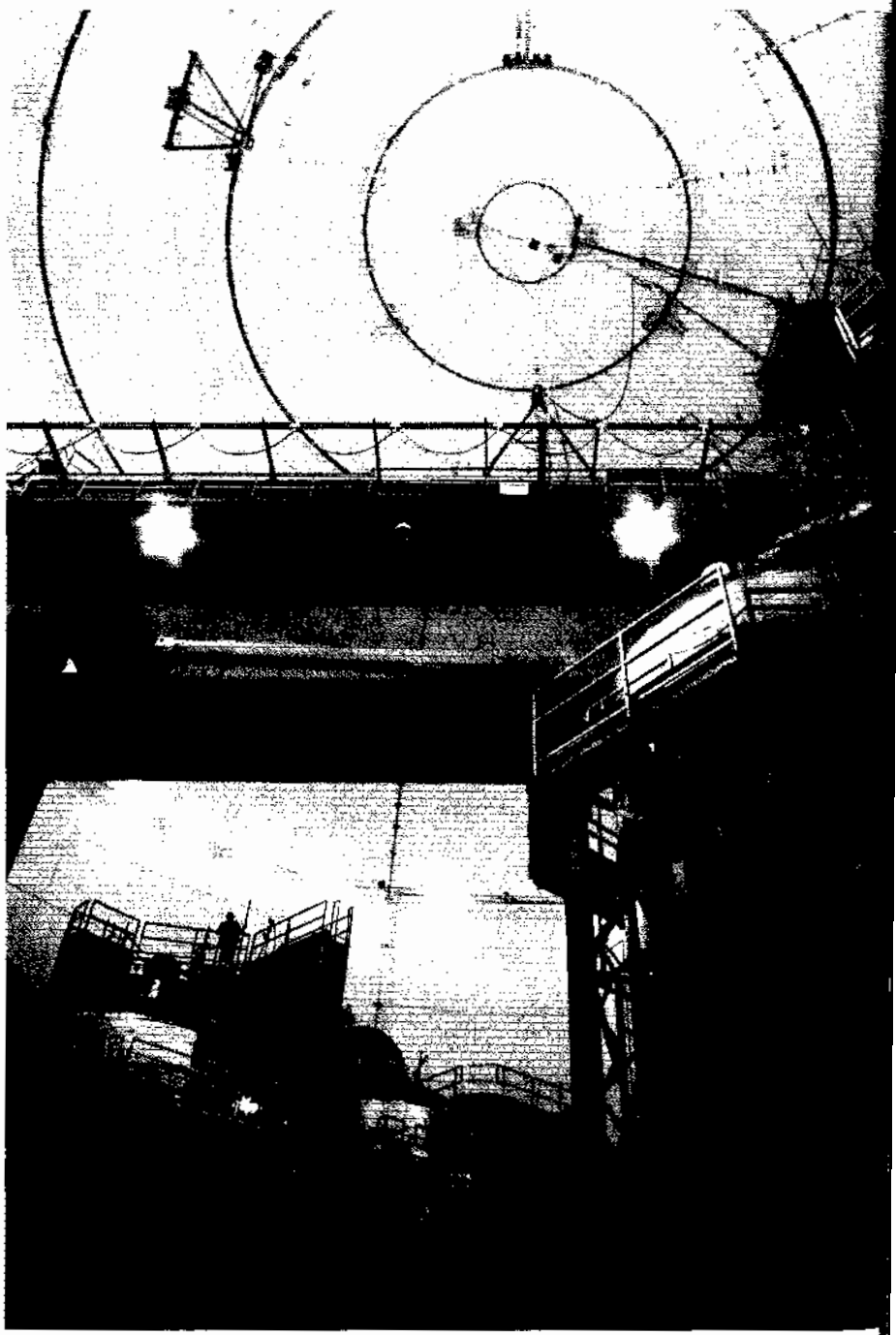
John Cagnetta
Nuclear Fuel Manager, Northeast Utilities; Chairman, Fuel Cycle Subcommittee, Nuclear Systems and Materials Task Force, EPRI

NDE and steam generators

EPRI is active in a number of areas in the field of nondestructive examination, including ultrasonic inspection, eddy-current devices, and development of a portable linear accelerator for radiography of primary-system components in a nuclear power plant. A recent innovation, called the adaptive learning technique, couples an ultrasonic inspection device with a small computer. This can produce highly accurate and reproducible results in the inspection of welds in reactor components and differentiate benign flaws that may exist from those that might pose a potential safety problem. Devices under development in these programs can also be used to inspect for possible flaws in turbine disks and rotors and to determine the condition and integrity of tubes in steam generators. (RP822, RP892, RP1125, RP1172, RP1395)

"NDE work is very, very vital and it's something we're pushing as fast as we can. Of all the work going on at EPRI that I'm aware of, this probably has the greatest near-term potential benefit to the utilities. As for the steam generator program, we're really just getting under way, but some of the preliminary results have already proved to be valuable. These results are, in fact, tending to confirm some of the suspicions and thoughts we had."

Robert Haueter
Director of Special Projects, Consumers Power Co., Chairman, Technical Advisory Committee, Steam Generator Owners' Group, and Member, Systems and Materials Task Force, EPRI

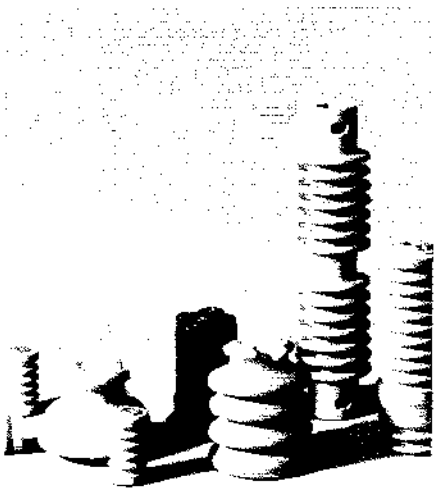


Polysil

Porcelain is the most widely used substance for electrical system insulators, but there's always room for improvement. Polysil*, a polymer-silica compound being developed by EPRI, has twice the dielectric strength of standard electrical porcelain, half the dielectric constant, and is highly resistant to impact. The easily molded substance requires no firing and can be produced at half the cost of porcelain. Polysil insulators are being field-tested on outdoor racks at substations in the United States and Mexico. Other potential applications include bushings and power poles. (RP480)

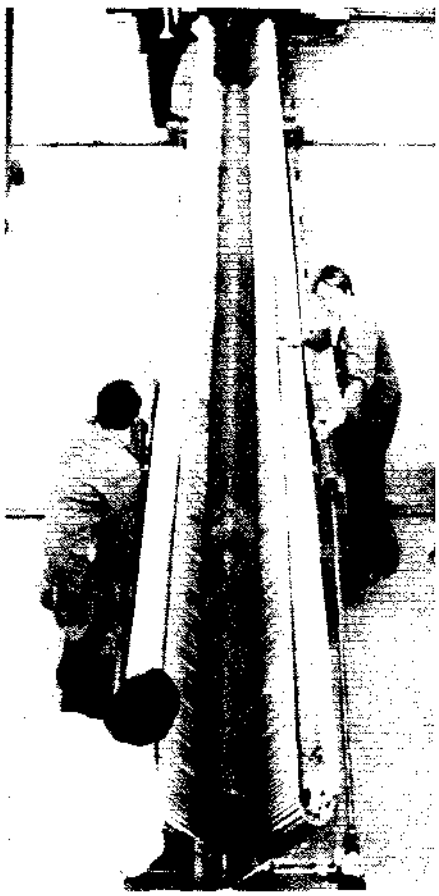
"Although we too often take improved technology for granted, it is not insignificant when a line item, such as a new Polysil insulator, can be produced at half the cost of porcelain insulators. Vermont's climate will provide a rigorous test for Polysil when the new insulators undergo field evaluation on GMP's system this year."

John V. Cleary, Jr.
Executive Vice President, Green Mountain Power Corp.



Fly ash pole

EPRI is building a better power pole out of fused fly ash and scrap glass. Tests indicate this material will have a longer life and require less maintenance than the traditional wood utility pole. Contractor ECP Inc. developed the process for extruding, drying, and firing the material. Sections measuring 8 in × 8 in × 30 ft (203 mm × 203 mm × 9 m) have been produced. EPRI's goal is a competitively priced, 40-ft (12 m) pole, the equivalent of a Class-1 wood utility pole. (RP482, RP851)



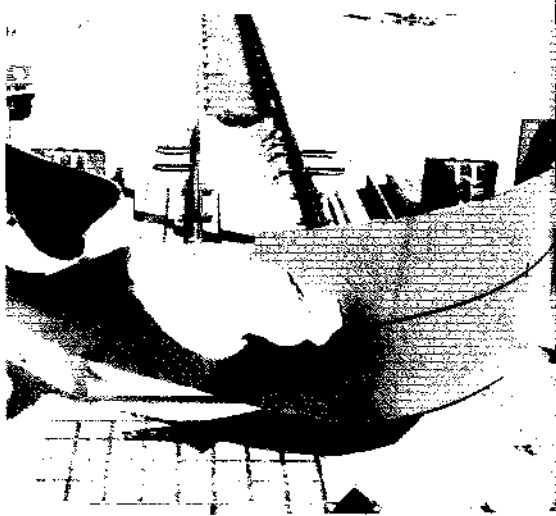
*Polysil is an EPRI trademark.

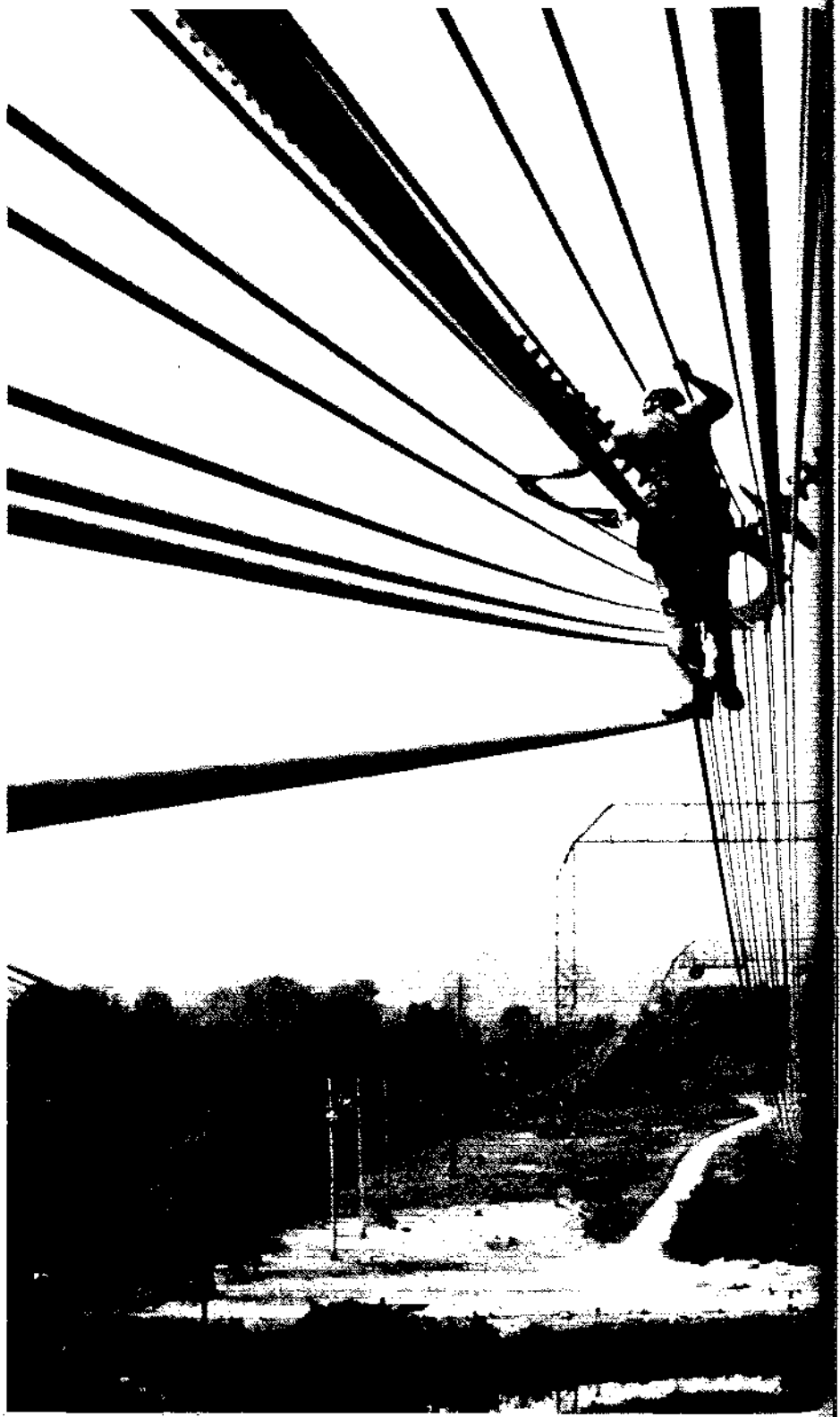
Turbine missile

In the highly unlikely event that a steam turbine rotor should fail, some of the heavier metal fragments from rotating parts might penetrate the steel casing. No accident has ever produced such turbine missiles in the 400 turbine-year operating experience of U.S. nuclear power plants. Nevertheless, the effects of hypothetical turbine missiles are considered in nuclear plant design. Full-scale tests are yielding data to measure the protection provided by the casing and by the concrete plant walls 2–6 ft (0.6–1.8 m) thick. Two tests run at Sandia Laboratories' rocket track in the New Mexico desert with a 1.5-ton missile driven at 327 mph into a simulated turbine casing showed that two-thirds or more of the missile energy is absorbed by the casing. Full-scale impact of concrete structures will be tested in 1979. (RP399)

"The turbine missile question has been raised by NRC and has significantly affected plant design—specifically, plant arrangement. This research has gone directly to the heart of the matter: what really would happen if a turbine rotor part were to fly out. And the actual tests at Sandia have demonstrated that this is not serious, the turbine casing retains a lot of the energy of the missile, and the containment and many other buildings of similar strength would not be penetrated by such missiles."

William Cahill
Vice President, Quality Assurance and Reliability, Consolidated Edison Co. of New York; Chairman, Safety and Analysis Task Force, EPRI



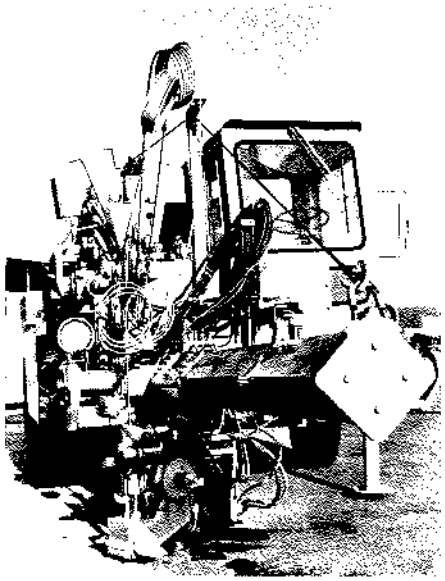


Project UHV

Transmission line voltages are rising—and greater efficiency in moving large blocks of power is one of the reasons why. EPRI's Project UHV constitutes a major effort to have ultrahigh voltage transmission technology (up to 1500 kV) available when utilities need it. Long-term research into areas such as conductor selection, insulator performance, and nonbiological effects of electric fields is being carried out at General Electric Co.'s test facility in Pittsfield, Mass. Facility resources include a three-phase, 1500-kV test transmission line, a contamination chamber 80 ft (24 m) in height, and corona cages. Next on the EPRI drawing board: a reconfiguration of the transmission line for HVDC testing. (RP68, RP566)

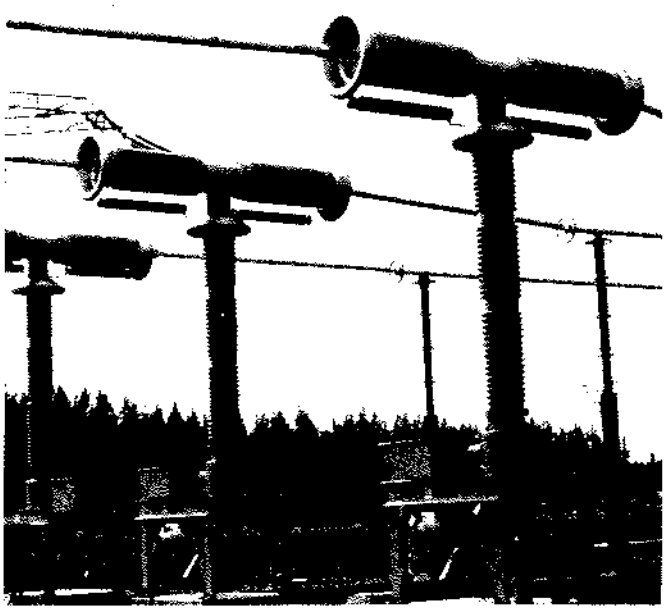
"Project UHV is both the today and the tomorrow of transmission lines. From this research, the planner and designer are shown how to best pattern the EHV–UHV line to the real world, and the real world is shown that it can live with that design."

George Elder
Engineer, Transmission Research, Los Angeles Department of Water and Power; Chairman, Transmission Lines Subcommittee, AC Overhead Transmission Task Force, EPRI



Concrete cutter

Before trenches for underground utility cables can be dug, any overlying concrete must be sectioned by jackhammers or saws and removed by backhoes. That slow sectioning job may be expedited by the water-jet concrete-cutter vehicle developed by Flow Industries, Inc., under EPRI contract. The vehicle's boom-mounted cutting unit uses multiple nozzles, each expelling a continuous stream of water at pressures up to 56,000 psi (386 MPa) to cut through up to 8 in (203 mm) of concrete at advancement rates of 2 ft (610 mm) per minute. Only one operator is required. Four host utilities are scheduled to field-test the prototype for six months each. (RP7860)



Reactor/capacitor switch

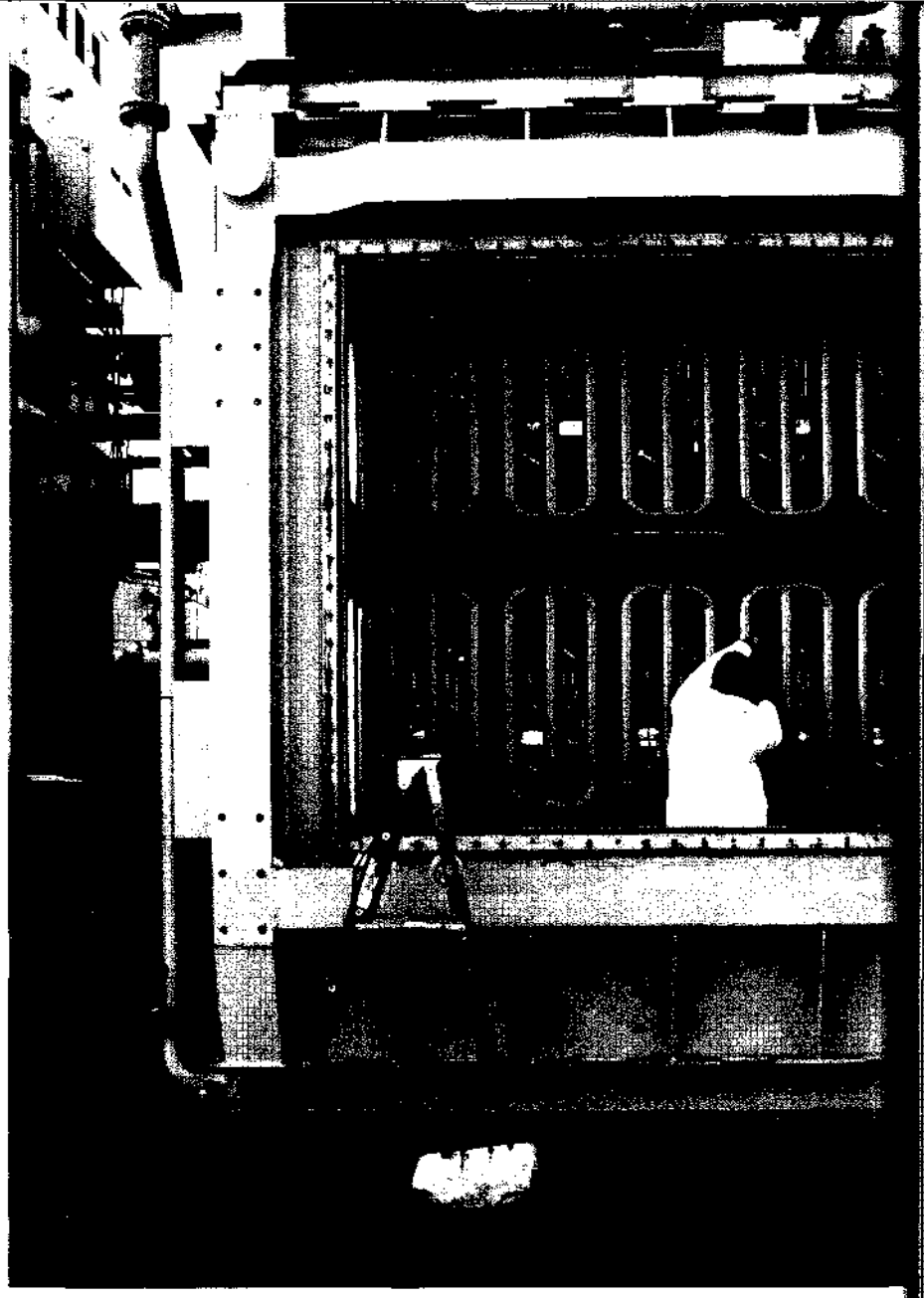
The job of switching EHV capacitors or reactors for compensation of long transmission lines is beyond the capability of conventional disconnect switches, and the use of costly circuit breakers is equally unacceptable. To solve the problem, EPRI and Bonneville Power Administration have cofunded development of a family of reactor/capacitor switches that will allow the lower-cost switching of large capacitor and reactor banks. The prototype three-phase switch developed by Westinghouse Electric Corp. uses two interrupters per phase for 550-kV application. Field tests on BPA's system were recently completed, and the switch is now in service for a one-year field evaluation. (RP655)

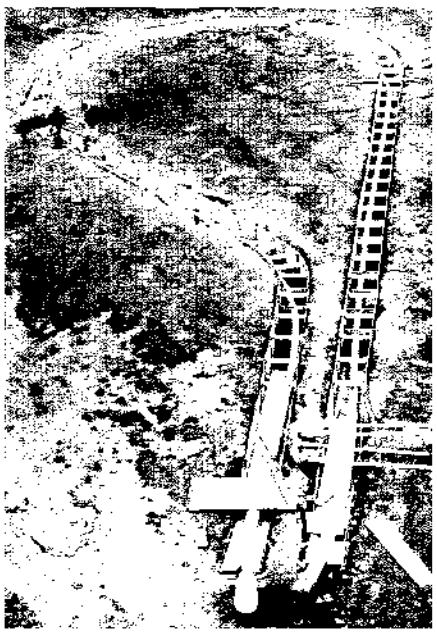
Dc link

HVDC transmission could soon be an important means of supplying bulk power to congested cities. But first, a compact dc converter station appropriate for metropolitan locations must be developed. In a joint effort with General Electric Co. and Consolidated Edison Co. of New York, EPRI has constructed a prototype dc link, including two 100-MW converter terminals, at Astoria station, New York City. Testing of this compact, gas-insulated, dead-tank, low-profile outdoor converter technology is now under way. As a result of this research, dc compact terminal technology will be available to electric utilities by 1980. (RP213)

"The prototype dc link shows how a 'pilot plant' can bring about practical solutions to a variety of problems that always arise in applying a new and developing technology."

William R. Johnson
Chief Electrical Engineer, Pacific Gas and Electric Co., Chairman, DC Link Steering Committee, EPRI



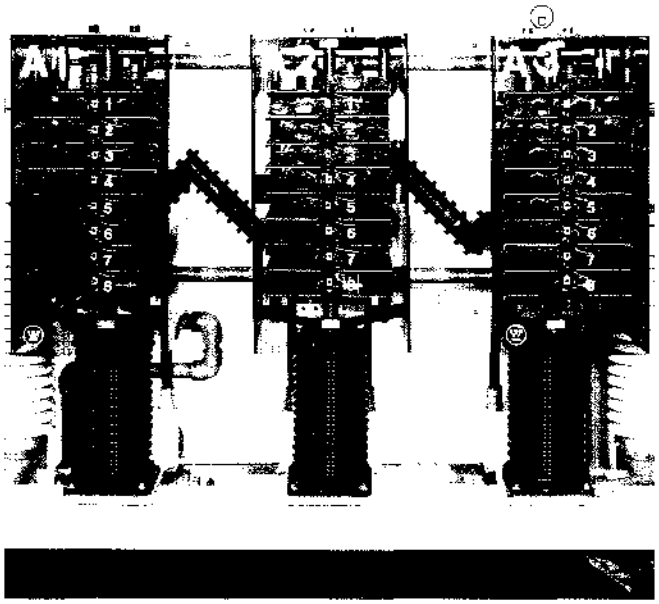


Flexible gas cable

Greater handling and shipping ease and fewer field assembly problems are some of the advantages flexibility would confer on gas-insulated transmission cables. EPRI is developing a flexible 345-kV gas-insulated cable with the help of Gould Inc. A prototype section 100 m (330 ft) in length and 300 mm (1 ft) in diameter (approximately 230 kV) was shipped on a reel to EPRI's underground transmission test facility at Waltz Mill, Pennsylvania, where it weathered a 300-kV withstand test before and after a pull through a trench with an S-bend and a return loop. Another flexible cable feature that will reduce costs is automated production, rather than assembly by hand. By midyear, EPRI expects to begin installation of a cable-manufacturing machine. (RP7837)

"Flexible gas-insulated cables, as opposed to rigid cables, have distinct advantages: low installation cost, low labor cost associated with manufacturing, and low cost of insulating spacers."

Matthew S. Mashikian
Supervisor, Engineering Research Dept., Detroit Edison Co.; Chairman, Gas Cable Subcommittee, Underground Transmission Task Force, EPRI



VAR generator

A static volts-amperes-reactive (VAR) generator will support voltage, aid in stability, and control VAR on transmission lines—an important job as more and more power generation is located far away from load centers. With funding from EPRI and Minnesota Power & Light Co., Westinghouse Electric Corp. has manufactured just such a device. Made up of thyristor-controlled capacitor banks and a thyristor-controlled reactor (controls shown), the generator offers fast response, low power losses, and reduced maintenance. The prototype is now being tested at the utility's Shannon substation. (RP750)

Information, please . . .

EPRI offers a variety of information on technologies being developed by the Institute—reports, computer programs, exhibits, and films.

Information on EPRI research and development comes in all shapes and sizes. Available materials—technical and nontechnical—include reports, computer programs, films, and the *EPRI Journal.* A guide to this information follows.

Technical reports

Since its formation, EPRI has published more than 1000 technical reports. These include reports on EPRI's ongoing and completed research projects, special reports, workshop and seminar proceedings, and technical planning studies. Individual reports are free to member utilities, government agencies, and foreign organizations with which EPRI has information exchange agreements. Others are charged a fee. Summaries of technical reports are also available.

Contact: Research Reports Center, P.O. Box 10090, Palo Alto, California 94303, (415) 961-9043.

Planning and assessment

Available EPRI publications prepared by the Planning Staff include the *Research and Development Program Plan for 1979–1983* (two volumes: overview and detailed program descriptions) and the *Technical Assessment Guide* (a description of the methods used by EPRI to assess alternative utility options). These documents, available in limited quantities, are free of charge.

Contact: Research Reports Center, P.O. Box 10090, Palo Alto, California 94303, (415) 961-9043.

Research accomplishments

EPRI achievements are described in two documents prepared by the Planning Staff: *Research Accomplishments and Progress on Continuing Projects,* and *An Executive Summary of EPRI Research Accomplishments.* These documents are available in limited quantities, free of charge.

Contact: Research Reports Center, P.O. Box 10090, Palo Alto, California 94303, (415) 961-9043.

On-line data base

EPRI's Research and Development Information System (RDIS), a computerized, on-line data base, contains information on some 4400 research projects sponsored by EPRI and by individual electric utilities across the United States. Direct access to the system is obtained by interactive terminal over telephone lines for an hourly fee. EPRI members and utility participants may also request searches by letter or phone at no charge. Others submit requests by letter.

Contact: Ken Andrews, Manager, RDIS, EPRI, (415) 855-2155.

Material contained in the RDIS data base is published annually in EPRI's *Digest of Current Research.* A quarterly publication, *Research and Development Projects,* briefly describes EPRI projects. Both publications are free on request; however, supplies are limited.

Contact: Research Reports Center, P.O. Box 10090, Palo Alto, California 94303, (415) 961-9043.

Computer programs

EPRI has established the Electric Power Software Center, which is managed by Technology Development Corporation. The center distributes EPRI-developed computer programs for utility industry applications. It will also update programs and correct bugs as they are discovered. Fees for the center's services will be available shortly.

Contact: Leroy Krider, Technology Development Corp., 155 Moffett Park Drive, Bldg. C, Sunnyvale, California 94086, (408) 734-5500.

Patents

As a result of its R&D projects, EPRI has 197 inventions available for licensing. These include 36 inventions for which

patents have been granted and 161 for which patents are pending.

Contact: EPRI, Manager of Patent Administration and Licensing, (415) 855-2216.

Journal

The *EPRI Journal* (10 issues a year) presents an overview of Institute activity, including results of EPRI research, state-of-the-art features, an update on division research activities, and reports on recent Institute developments. The *EPRI Journal* is distributed without charge.

Contact: EPRI, Communications Division, (415) 855-2731.

Educational exhibits

Roger Tierney Associates, in cooperation with EPRI, is developing a series of technical exhibits that utilities may use as public information tools. Each exhibit will consist of a display unit and interchangeable graphic panels depicting various topics. Solar energy, coal, energy and the economy, and the Centennial of Light (technological progress) are among topics now available; other energy topics are planned. Prices will vary according to type of exhibit unit and the number and type of topics.

Contact: Roger Tierney Associates, Inc., 2955 McCall Street, San Diego, California 92106, (714) 222-9900.

Energy films

EPRI is planning a series of 14 energy technology films for general audiences. The first film, *The Electric Story: Coal,* is now available to EPRI members at $125 per copy; price to nonmembers is $250. Another Institute-produced film, *Energy Realities,* is available at $135 per copy.

Contact: Research Reports Center, P.O. Box 10090, Palo Alto, California 94303, (415) 961-9043.

Guide

Early this year, EPRI will begin distribution of a quarterly technical resource catalog, complete with listings of technical reports, licensable inventions, computer programs, films, and other material of industry interest. This free catalog will replace the earlier Publications List.

Contact: Research Reports Center, P.O. Box 10090, Palo Alto, California 94303, (415) 961-9043.

Information Service catalog

The Information Service catalog tells how to order miscellaneous EPRI information, including *EPRI Journal* reprints and special issues, speeches, and the energy technology timetable poster.

Contact: EPRI, Communications Division, (415) 855-2731.

At the Institute

Coal Wastes Into Ocean Reefs

Utilities may someday be able to use the ocean for the safe disposal of wastes from coal-fired power plants. This would be an attractive option for utilities near coastal areas.

Currently, most of the 60 million tons of waste products resulting each year from fossil-fuel power plant operations and pollution control equipment are disposed of in pits, ponds, and landfills or are used in roadbed construction.

EPRI's new five-year, $3 million project calls for researchers to evaluate the environmental, engineering, and cost aspects of using chemicals to solidify the waste materials from coal-burning power plants into concretelike blocks. Researchers will build an artificial reef under the ocean with 700 chemically treated and compacted 1-m^3 blocks of coal wastes. (The reef formed will be about the size of a small three-bedroom house.) The selected site for the experiment is off the south shore of Fire Island, Long Island, New York, at a depth of about 65 ft.

Tests of the artificial reef will be complemented by a laboratory program in which sample evaluations by ultrasonic studies and by direct mechanical and chemical techniques will identify any changes in physical characteristics, such as erosion, corrosion, or leaching.

According to EPRI, the artificial reefs could be used exactly as are natural reefs—for fishing or as a breakwater to protect harbors or beaches.

The costs for chemically solidifying the wastes into artificial reefs in the ocean appear to be economically acceptable, according to two years of preliminary studies conducted in Conscience Bay, Long Island, by the Marine Sciences Research Center and IU Conversion Systems, Inc., Philadelphia, Pennsylvania.

"But even if no significant savings in costs accrue in some cases, marine barrier reefs would alleviate problems in the disposal of the very large amounts of coal wastes now being produced," according to Dean Golden, EPRI project manager. Furthermore, he says that this type of research takes on added importance with the National Energy Plan's call for the country's electric utilities to increase coal use.

The cost of the study is being shared by EPRI, the Department of Energy, the Environmental Protection Agency, the New York State Energy Research and Development Authority, and the Power Authority of the State of New York. The actual research will be conducted by the Marine Sciences Research Center of the State University of New York.

Small-Utility Workshop

There are approximately 3500 electric utilities (public and investor owned) in the United States, and of these, the vast majority service fewer than 10,000 customers. More than 85% of these utilities supply a total electric capacity demand of less than 100 MW. Because of their large numbers, it is something of a problem for EPRI staff to become acquainted with the unique characteristics of these "small" utilities and determine the nature of their R&D needs.

To improve communications between EPRI and the small-utility sector, on November 15 and 16 EPRI conducted a small-utility workshop in Kansas City. Representatives from member utilities, as well as the staff of the American Public Power Association, National Rural Electric Cooperative, and the Edison Electric Institute, attended the workshop. In his keynote address, Robert Cleveland, president of Buckeye Power, Inc., set the tone of the workshop by saying, "Much of the research work that EPRI is now doing is just as important and useful to the small utilities as it is to the larger ones." He urged the representatives at the workshop to get involved in the management of EPRI and to confer with persons representing them on the Board of Directors and the Research Advisory Committee.

Briefings were given by EPRI technical staff on the R&D programs of particular value to smaller utilities. Following these, the attendees split into two working-group sessions, during which the utility representatives described the technical problems plaguing their systems that they would like resolved through specific R&D.

A comprehensive set of recommendations was developed during these working sessions. In the generation group, the R&D activities recommended included research on coal and oil mixtures, cycling operation of baseload-designed fossil plants, improved valve design, and reliability.

The area of transmission and distribution included research to develop pole testers that would test for conditions of dry rot in transmission poles, develop lightweight polymer distribution insulators, and field-test lightning arresters.

As a result of this exchange of information, the EPRI staff came away with recommendations for 33 research projects that are being incorporated into their R&D program planning. The small-utility representatives came away with an understanding of the benefits to be gained from participation in EPRI's R&D program planning.

SHAC Catalog

Utilities and their customers, contractors, energy consultants, and architect-engineers may find value in a catalog of solar heating and cooling (SHAC) computer programs. The catalog is being prepared for EPRI by Arthur D. Little, Inc., as part of an effort to evaluate and assess SHAC computer programs of universities, manufacturers, research institutions, and utilities.

To assist in this work, utilities using SHAC computer models that have not been contacted are asked to write Richard Merriam, Arthur D. Little, Inc., Acorn Park, Cambridge, Massachusetts 02140, or phone (617) 864-5770, ext. 887.

The information collected will be used to determine how solar computer programs can aid in utility planning, load forecasting, and the analysis of utility rate structures.

EPRI and British Test High-Sulfur Coals

An agreement has been signed by EPRI and the British Gas Corp., London, to test U.S. eastern caking coals, which could lead to their use in a new, more efficient type of power plant.

The $3 million research program will start in April 1979 at the British Gas Corp.'s slagging gasifier test plant in Westfield, Scotland. If the Westfield plant can use the U.S. coal under the full range of load changes required of a plant operating in a power-generating network, it would mean that high-sulfur coals from the eastern U.S. could be used in gasification–combined-cycle power plants.

In these new plants, coal is gasified and the resultant fuel gas is burned in a combustion turbine; the exhaust heat from the combustion turbine is used to raise steam, which drives a steam turbine. According to EPRI, gasification–combined-cycle plants have the potential of providing electricity at competitive prices and of meeting tight environmental standards more easily than other coal-fired power plants. In addition, they have the potential for using less coal and water than a conventional plant, while producing equal amounts of electricity.

The test program is scheduled to run for three months. If successful, further efforts could lead to a large-scale demonstration of this technology within the next 10 years.

FFAS Annual Review

Huberto R. Platz, vice president–engineering, Wisconsin Electric Power Co., posed a number of questions at the recent annual review held by EPRI's Fossil Fuel and Advanced Systems Division in Palo Alto, California. The purpose of the meeting was to brief members of the division task forces and committees on division activities. Representatives from federal, state, and local governments, and environmental groups also attended the two-day session.

Cooling-Tower Seminar

A cooling-tower seminar sponsored by the International Association of Hydraulic Research was held on November 13 and 14 at the Electricité de France laboratories in Chaton, France. The seminar was hosted by Messrs. Lionel Candron, Directeur, Etudes et Recherches of EdF, and Jean Chevalier, IAHR council member.

Technical papers on the performance and environmental impact of cooling towers and new cooling-tower technology were presented at the meeting, which was attended by 50 European and American researchers. The seminar was followed by an active session of technical information exchange.

John Bartz, EPRI project manager in the Water Quality Control and Heat Rejection Program, served as panel moderator in a session on cooling-tower performance. John Maulbetsch, EPRI program manager, is a member of the Cooling Tower Group (steering committee) of the IAHR section on nuclear hydraulics.

Residential Solar System

During the next two years, researchers will monitor a passive heating and cooling system built into a new Stockton, California, home by architect-builder Glen H. Mortensen and Pacific Gas and Electric Co. The home was built and is owned by Mortensen, and the test program is being sponsored by EPRI and PG&E.

Passive systems differ from active ones in that they use architectural design to collect, store, and transfer the sun's heat rather than active components, such as solar collectors and mechanical equipment. Like active systems, passive ones may require electric backup during periods of extended cloudiness.

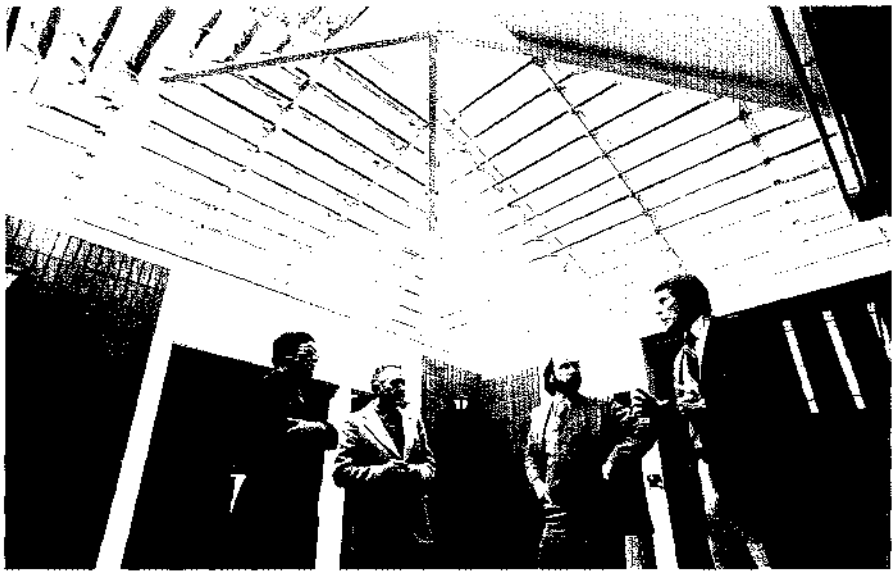
The Stockton home combines a forced-air system with an electric heat pump (a device that heats or cools a home and uses less energy than conventional electric heating). The sun's energy enters a solarium, or skylight, to heat the house. Excess energy is stored in water-filled tubes, concrete block interior walls, and a bed of rocks. Cooling can be accomplished in one of two ways: by activating the heat pump or by forcing air over the rockbed (which has been cooled by night air) and then circulating the air in the home.

The EPRI–PG&E project involves the installation of some 30 sensors for measuring temperature, humidity, wind speed, and sun intensity. The sensors will collect data to help researchers determine the performance of the system while the home is occupied by a family.

The data collected will be compared with computer-predicted performance by the PG&E subcontractor, Berkeley Solar Group, Berkeley, California, as well as with data collected from a conventional electric heating and cooling system at another home in the same area.

"This project is one of several that EPRI is sponsoring to help the utilities and their customers identify the best ways, in terms of cost and energy efficiency, to combine solar heating and cooling systems with today's electric systems," says EPRI Project Manager Gary Purcell.

A Stockton, California, solar home, being studied as part of a monitoring project sponsored by EPRI and PG&E, features louvers in its solarium (skylight) through which the sun's energy enters to heat the home. The energy is stored in brick walls (left and center), water-filled concrete tubes (right), and a rockbed beneath the floor of the house. The louvers govern how much solar energy enters and can be manually opened and closed. Discussing some of the engineering aspects of the solar heating and cooling system are (from left) Rich Chan, PG&E, Stockton Division, solar coordinator; Glen Mortensen, architect-builder; Mike Beanland, PG&E, San Francisco, solar energy applications engineer; and Gary Purcell, EPRI solar heating and cooling project manager.



Study of Scrubbers Under Way

The most comprehensive analysis to date of the effectiveness of sulfur dioxide scrubbers—the pollution control devices used by utilities on coal-fired power plant stacks—is being conducted for EPRI by Black & Veatch.

Scrubbers have been used commercially by the utility industry since the late 1960s. In a typical scrubber system, the stack gas is mixed with a lime/limestone solution that absorbs and reacts with the sulfur dioxide to form a disposable solid.

Researchers are field-testing scrubber systems at four utility sites through June 1979 to determine the system's capabilities for removing government-regulated stack gas pollutants, such as sulfur dioxide and nitrogen oxide, and nonregulated emissions, including organic compounds and trace elements. The four sites included in the study are Pennsylvania Power Co., Bruce Mansfield Station No. 1 or No. 2; Columbus and Southern Ohio Electric Co., Conesville Unit 5; Northern States Power Co., Sherburne County Station No. 1 or No. 2; and The Montana Power Co., Colstrip No. 1 or No. 2.

In addition, researchers are investigating the economics of scrubber systems—what they cost to build, operate, and repair—and will perform an engineering analysis to determine the quality of equipment designs and operation.

Richard Rhudy, EPRI project manager, reports, "This effort is providing the utilities with information to assist them in selecting the most economical and effective pollution control equipment to meet current and future government emission regulations."

He notes that this analysis, unlike others, will include a comparison of the costs, operation, and removal capabilities of the scrubber systems under consideration.

Black & Veatch is being assisted by several subcontractors, including TRW, Inc., in Redondo Beach, California; Pedco Environmental Specialists, Inc., Cincinnati, Ohio; and Meteorology Research, Inc., Altadena, California.

Calendar

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

APRIL

1–4
Edison Centennial Symposium
San Francisco, California
Contact: Beth Pforr (415) 855-2133

10–11
Over/Under Capacity Planning Workshop
Columbus, Ohio
Contact: Eugene Oatman (415) 855-2629

17–27
Communications Workshops
Denver, Colorado (17)
Portland, Oregon (18)
Chicago, Illinois (24)
Washington, D.C. (25)
New Orleans, Louisiana (27)
Contact: Robert Taylor (415) 855-2253

22–25
Solid Waste R&D Needs for Emerging Coal Technologies Seminar
San Diego, California
Contact: Dean Golden (415) 855-2516

MAY

Date to be announced
2nd EPRI Symposium on Electric Utility Load Forecasting
Site to be named
Contact: Barbara Williams (415) 855-2624

31–June 1
Over/Under Capacity Planning Workshop
Denver, Colorado
Contact: Eugene Oatman (415) 855-2629

Advances in NO_x Control

The latest advances in the technology to control oxides of nitrogen (NO_x) from pulverized-coal–fired steam generators were presented at the second EPRI NO_x Control Technology Seminar in Denver.

The objective of the meeting was to review and discuss the efficiency, cost, and reliability of emerging NO_x control technologies. This is a rapidly changing field because of the increasingly stringent NO_x control requirements being established under the 1977 Clean Air Act Amendments, as well as state and local regulations.

The seminar, sponsored by the Air Quality Control Program of the Fossil Fuel Power Plants Department, covered NO_x control by burner design, combustion modification, and flue gas treatment. It was attended by more than 200 representatives of the utility industry, Environmental Protection Agency (EPA), Department of Energy, manufacturers of utility boilers and auxiliary equipment, and research groups and consultants.

Progress was reported on two pulverized coal-combustion processes for controlling NO_x that are being tested on a pilot scale. These advanced processes (noncommercial) are yielding emissions well below those of conventional coal burners. They are reportedly producing less than 200 parts per million of NO_x (at 3% oxygen concentration) under most operating conditions.

Both processes use the concept of staged combustion to delay the rate of fuel and air mixing. In staged combustion, the fuel is partially burned with less than the chemically required amount of air, and the remainder of air is added at a later stage. The initial deficiency of air inhibits the oxidation of the nitrogen in the fuel.

One of these staged combustion processes is being developed by the Alliance Research Center of Babcock & Wilcox Co. under EPRI sponsorship. The second is being developed by the Energy and Environmental Research Corp. in Santa Ana, California, under EPA sponsorship.

Future plans call for both processes to be tested on a large scale under typical furnace operating conditions.

Representatives from four utility boiler manufacturers, Babcock & Wilcox Co., Foster Wheeler Energy Corp., Riley-Stoker Corp., and Combustion Engineering, Inc., discussed the progress each has made in designing and manufacturing conventional coal burners with reduced NO_x emissions. Progress during the past several years has focused on refining existing burner designs so fuel-air mixing can be delayed and desirable conditions created to minimize NO_x formation. The potential for low NO_x emissions with conventional burners is less than with the advanced concepts because the fuel-air mixing cannot be delayed to as great an extent.

NO_x emissions characteristics from several operating power plants were reported at the seminar, including reductions that have been achieved by Arizona Public Service Co. at its power plant in Four Corners, New Mexico. Modifications in burner design have reduced NO_x emissions by 45% (compared with uncontrolled emissions) on Units 1 and 2.

Also reported were results of EPA-funded field tests conducted by Exxon Research and Engineering Co. in Linden, New Jersey. In these tests, the influence of combustion modification (another method of reducing the rate of fuel-air mixing in existing power plants) was studied. Robert Hall and David Lachapelle, EPA project officers, reported reductions as high as 40% (compared with uncontrolled emissions) under some test conditions.

Possible adverse side effects of these NO_x control techniques include increased furnace slagging or fouling and the accelerated corrosion of furnace water-wall tubes. This could limit the degree of staged combustion or combustion modification that can be practically applied and thus the ultimate level of NO_x reduction. These side effects are under additional study by EPRI and other research groups.

The seminar was the first of its type to devote an entire session to NO_x control by flue gas treatment, which is a post-combustion treatment process. This approach involves chemically reducing the

oxides of nitrogen in the furnace to nitrogen and water. Although this technology is inherently more complicated and expensive than combustion control, its high NO_x removal efficiency is being considered by EPA and other regulatory agencies for future application to fossil-fired power plants.

A variety of postcombustion treatment processes are being investigated by a large number of research organizations, including EPRI and manufacturers of chemical process equipment. The seminar covered the technical status of five such processes that are currently being developed, including selective noncatalytic (Exxon), selective catalytic (Hitachi-Zosen, Babcock-Hitachi, Kawasaki Heavy Industries), and simultaneous NO_x and SO_x (Universal Oil Products, Inc.).

Several presentations described plans for pilot-scale tests to develop and assess flue gas NO_x treatment under realistic operating conditions. Yasuyuki Nakabayashi, from the Electric Power Development Co. in Japan, described plans for a 250-MW coal-fired test facility near Takahara, Japan. Also reported were EPA plans for two pilot plants (both less than 1 MW) in Florida and Georgia, and EPRI plans for a 2.5-MW pilot plant in Colorado.

Communication Meetings Scheduled

How can EPRI help member utilities better communicate the results of EPRI research to customers, utility commissions, business leaders, the news media, and other groups in their service area? How can it be assured that EPRI information, such as research reports, are received by the proper people at utilities?

These are the types of questions to be explored during a series of EPRI meetings with public information staff members and information coordinators of EPRI member utilities. Aimed primarily at utility news bureau editors, media relations representatives, community relations managers, and house publications editors, the meetings should help EPRI improve its communications with utility representatives responsible for public and news media contacts.

The meetings are planned for April 17, Denver, Colorado; April 18, Portland, Oregon; April 24, Chicago, Illinois; April 25, Washington, D.C.; and April 27, New Orleans, Louisiana. For more information, please write Robert Taylor at EPRI or call (415) 855-2253.

CFC Officers Briefed

Officials of the National Rural Cooperative Finance Corporation (CFC) were briefed on EPRI's program by members of the Washington staff. The CFC finances rural electric cooperative utilities, 211 of which are EPRI members. Discussing EPRI's program are (from left) Robert Loftness, director of EPRI's Washington office; Wayne Beatty, EPRI field engineer; Kent Sullivan, CFC management trainee; Clyde Denton, CFC information and membership relations officer; J. K. Smith, CFC governor; and George King, CFC technical staff member.

Washington Report

Tapping the hydroelectric potential of small dams is a key commercialization goal of the Department of Energy. The problems are both economic and institutional.

During 1978 DOE set its commercialization wheels in motion by identifying eight energy technologies as top candidates for transfer to the private marketplace. Included on the list was small, or low-head, hydroelectric power, a technology for producing electricity at small dams with a capacity of 15 MW or less.

Some might question why small hydro, a technology that has been used throughout the world for many years, might find itself on a commercialization list with other, newer technologies, such as solar hot water heating. Isn't small hydro already commercial?

The question was addressed by the DOE small-hydro commercialization task force, and its strategy report reads: "Although low-head hydro is a well-developed technology, the lack of new projects since World War II lends it the flavor of an emerging technology." Revitalization, then, is a key target—revitalization of the technology, of the industry to support it, and of interest among potential developers (utilities, municipalities, individuals, small companies, and others who may own dams).

Federal role

The federal participation in this process is managed by DOE's small-hydro program in the Office of Resource Applications (RA). Together with the Office of Conservation and Solar Applications, RA is the last step in a technology's orderly progression through DOE's path to commercialization. Heavy federal support characterizes early steps in the path: basic research is under the Office of Energy Research, and engineering development is the responsibility of the Office of Energy Technology. At the RA stage, DOE's focus is on increasing the private sector's involvement and decreasing the government's role.

"Our job is to get in, get an industry established, and get out," says Richard McDonald, DOE's resource manager for small hydro. "Picture the program as an hourglass. The sand runs through it every day."

The concept of resource manager is central to DOE's commercialization efforts. Each commercialization candidate is assigned such an advocate who integrates all agency efforts to transfer the technology to the private marketplace. McDonald is well-suited for the job. He not only served as chairman of the DOE small-hydro commercialization task force but also managed what is called the 90-day study of national hydroelectric power potential at existing dams when he was with the U. S. Army Corps of Engineers. That study indicated the promise of small hydro to help increase energy supply and displace fossil fuel use.

McDonald describes himself as the point man for small hydro, working with potential developers, utilities, other federal agencies, financial institutions, and other private-sector organizations "to promote the cause of small-hydro development in the United States." With a staff of four professionals, he does that by "helping the developer do his job in any way we can within our resources."

Developers need help

Most potential small-hydro developers (those who own dams), McDonald explains, are relatively small entities (individuals, small companies, municipalities, municipal utilities) who need help to surmount the financial and institutional obstacles inherent in developing a dam for hydroelectric power production. Front-end costs are high, both to determine if a site is feasible and to purchase capital equipment, and the license and permit process is often complex.

The reasons are manifold. One inherent problem with hydropower is the stiff competition developers face from other water users. McDonald explains, "The nation's streamflow is a scarce and valuable commodity for all kinds of purposes: water supply, irrigation, recreation. Al-

most every existing dam in the country is already being used for some productive purpose. We have to find out if there is a place for hydropower to fit in under the existing way the dam is utilized."

Potential hydropower developers also face the problem that many existing dams are in poor physical shape. To obtain a license, a developer may have to upgrade safety features or provide new equipment to facilitate fish migration. McDonald's office helps the developer coordinate these requirements with such agencies as the Corps of Engineers and the U.S. Fish and Wildlife Service.

Activities like these are part of what McDonald calls the institutional analysis function of his office—identifying legal, regulatory, and interagency barriers that inhibit or prevent rapid development of small-hydro sites. The engineering development function primarily concerns reducing the cost of small-hydro equipment, a major obstacle to potential developers. Large hydro plants are custom designed to squeeze every ounce of power possible out of the streamflow. At the present time, small plants are built the same way, and custom design means custom price. However, McDonald says the picture is changing, and manufacturers are starting to provide standardized designs.

"They're giving up a little bit of efficiency, a few kilowatthours, but if they can get the design standardized and bring in mass-production techniques, then we can really get the cost down."

His engineering development program will emphasize standardization this year, McDonald says. "That's where we think the biggest payoff is. Not just with the machines but also with standard ways to build powerhouse intake gates, control equipment, and other parts of a plant."

OPEC changed picture

McDonald believes that small-hydro's ability to compete economically with other energy sources is getting better each day. Many small-hydro plants were retired after World War II because of poor economics compared with large, central steam plants.

"The whole ball game has changed since the OPEC price hike," McDonald says. Higher oil prices, as well as increases in coal and nuclear costs, have helped put small hydro "squarely in the middle of the competitive range." Because half the capital investment is already in place with existing dams, he estimates that rehabilitation and retrofit projects can be built for between $700 and $1500 per installed kilowatt of capacity, with most projects falling between $1100 and $1200.

"Up until a few years ago it was ridiculous to think about that competing with coal plants at $200 and nuclear at $300. But the cost of these plants has gone into orbit." And pointing to the 14.5% rate increase in crude oil prices announced by OPEC in December, he commented, "Probably 15% more of my dams just fell into the feasibility range."

Feasibility studies

The largest share of funding for McDonald's office goes to feasibility studies and demonstration projects. Of the total $28 million FY79 budget, $10 million will support feasibility study loans. In FY78, the office awarded $2.9 million in grants for 57 studies to determine the feasibility of hydropower at existing dams. According to the American Public Power Association (APPA), the majority of the awards went to publicly owned utility systems. APPA is on record as strongly in favor of small hydro and Executive Director Alex Radin has said that the technology "offers local publicly owned utilities an excellent opportunity to generate their own power from a readily available, environmentally sound, and virtually free energy source." The results of the 57 feasibility studies are just now coming in, McDonald reports, and initial indications are very promising.

The National Energy Act (NEA) authorizes DOE to continue funding the feasibility studies for FY79 and FY80 by loans a developer would repay when a hydro site starts producing power. If a site is proved not feasible, however, the loan is canceled.

The small-hydro construction program is actually a demonstration program—DOE is sharing with developers the cost of rehabilitating existing dams for hydropower to demonstrate that the concept is commercially viable. The centerpiece of the program right now is the Idaho Falls demonstration project. DOE is helping the city of Idaho Falls rebuild and expand three hydroelectric dams damaged in the collapse of the Teton Dam several years ago. The three dams formerly produced a total of 7.4 MW; when completed in 1982, each will have a capacity of 8 MW. DOE is paying $7.2 million of the estimated $43 million project, with the city of Idaho Falls financing the rest through revenue bonds. (The bond referendum, incidentally, returned a 95% yes vote.)

In the next stage of DOE's demonstration program, the agency will fund a maximum of 25% of 6–12 additional projects. Proposals for these projects were submitted last November and those selected will be announced early this year.

Winding down

After this McDonald believes that the demonstration program will slow down. Although the NEA authorizes $100 million in construction loans for FY79 and FY80, no funds have yet been appropriated for FY79, and the FY80 request will be "at a very, very minimum level.

"I think from now on our activities will be less capital-intensive, less of an emphasis on spending money to get things done and more of an emphasis on providing services to developers."

In summing up the thrust of his program, he comments: "The thing we have to grapple with is how to get as much of this activity going as quickly as possible to revitalize the U.S. [small-hydro] industry, which will then develop a marketing organization and start to do our work for us. Eventually, the federal government can get its hands off and fall back into a traditional regulatory role such as FERC [Federal Energy Regulatory Commission] plays in hydroelectric development. Then DOE can go on and do business somewhere else."

R&D Status Report
FOSSIL FUEL AND ADVANCED SYSTEMS DIVISION

Richard E. Balzhiser, Director

CLEAN GASEOUS FUELS

*Studies show that coal gasification–combined-cycle (GCC) systems that use second-generation gasifiers offer marked advantages over systems that use direct pulverized-coal firing with flue gas desulfurization (*EPRI Journal, *July-August 1978, pp. 43–46). These systems present potentially competitive capital cost and cost of power, better resource utilization (more kilowatt-hours per ton of coal with less water and land usage), and the ability to meet stringent emissions standards. EPA's current plans call for even more stringent emissions standards by 1985, and under such circumstances, the cost advantage for GCC units will be further enhanced vis-à-vis direct coal firing. In 1978, important results were obtained in EPRI-supported projects at three major gasification pilot plants, confirming the promise of GCC technology and setting the stage for expanded development and subsequent demonstration in the mid-1980s.*

First-generation gasifiers are generally defined as those available commercially, such as the Lurgi, Koppers-Totzek, and Winkler gasifiers. Power systems based on such first-generation processes do not have as attractive an economic potential as that of second-generation systems, discussed below. Within the EPRI Clean Gaseous Fuels Program, there are three major second-generation gasification processes being developed—by Combustion Engineering, Inc. (C–E), British Gas Corp. (BGC), and Texaco, Inc.

Combustion Engineering entrained gasifier

This project comprises the design, construction, and testing of a gasification process development unit (PDU) located at C–E's Windsor, Connecticut, facilities (RP244-1). Gasification is accomplished in a two-stage atmospheric air-blown entrained unit. The fuel gas is cleaned of particulate matter (which is recycled to the bottom combustion zone), passed through a Stretford unit for H_2S removal, and fired in a package boiler (Figure 1). The design throughput is about five tons of coal per hour. The PDU was dedicated in October 1977, and a shakedown period (prolonged by a severe winter) was completed in May 1978. Since that time, six test runs logging over 400 hours of operation have been completed. The gas heating value has varied from 1.9 to 4.8 MJ/m³ (50–130 Btu/scf), and more work is required on controlling the air and coal flow rates to give consistent and complete data on heat and material balance. Nevertheless, most of the essential process principles have been successfully established, and there has been no sign of tars to date. The initial test

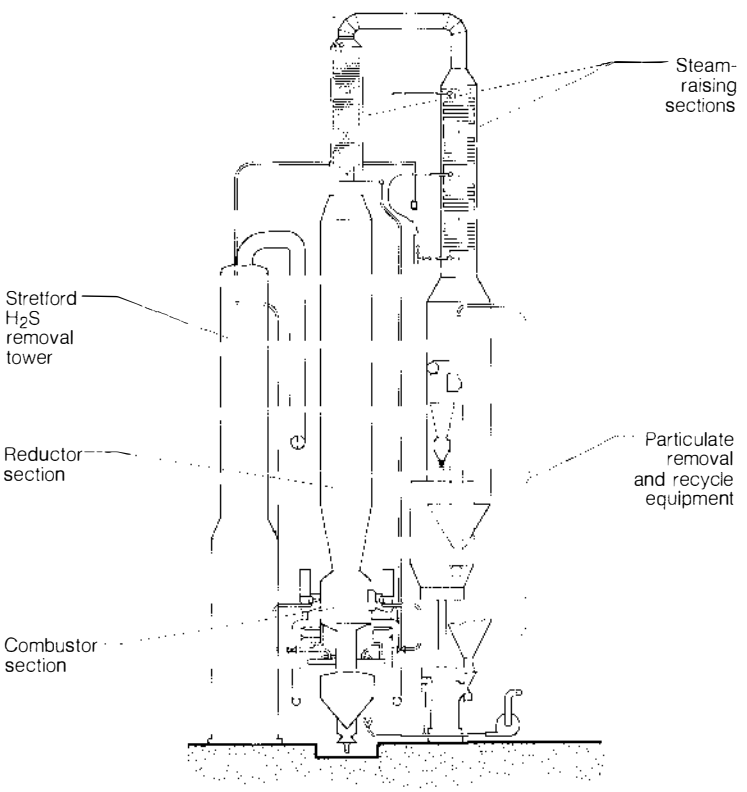


Figure 1 Combustion Engineering's two-stage atmospheric entrained gasifier. Product gases leave the gasifier, pass through the crossover duct at the top, and descend through a cooling section to the gas cleanup systems.

program based on Pittsburgh No. 8 coal is due for completion by September 1979. The project is jointly sponsored, with DOE providing 66% of the funding, EPRI about 20%, and C–E about 14%.

A proposal based on this technology was selected by DOE in May 1978 under the power utility category of responses to DOE's RFP for fuel gas demonstration plants. A contract for the Phase I design, to be funded entirely by DOE, is currently being negotiated. Fuel gas from the proposed plant would be used to retrofit a 150-MW natural-gas-fired boiler at Gulf States Utilities Co.'s plant in Lake Charles, Louisiana. This technology, if successfully developed, promises the attributes of design simplicity and low-cost construction, absence of tar production (obviating complex downstream processing), and the ability to process a wide range of U.S. coals.

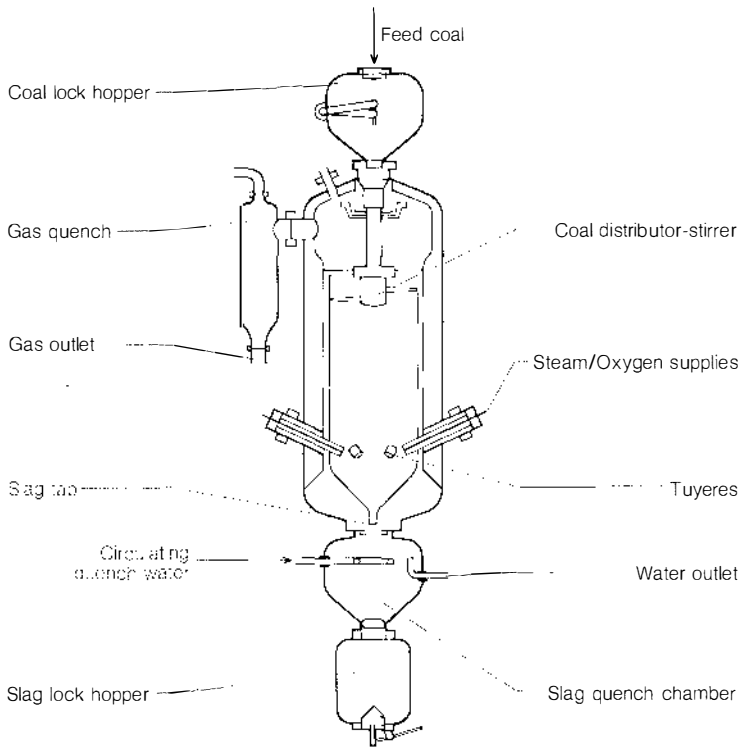
British Gas Corporation slagging gasifier

In the period 1975–1977, EPRI and 13 U.S. oil and gas companies supported the development of the BGC slagging gasifier at Westfield, Scotland. In this project, a Lurgi dry-ash unit was converted to operate as a slagging unit.

In the commercial Lurgi dry-ash gasifier, excess steam is injected at the base as a quench to keep the ash below the clinkering temperature. When the bottom of the gasifier is deliberately operated at the higher slagging temperature, throughput is tripled and steam consumption is reduced 5–8 times, leading to greater efficiency and less waste liquor for treatment. In addition, the slagging zone provides a method for complete gasification of the tars (which are produced in any countercurrent moving-bed gasifier) by injection through the tuyeres (Figure 2). The initial development program, including a 23-day run on the 13-t/h unit at Westfield, was completed in the summer of 1977 (RP407).

Conoco (Continental Oil Co.) submitted a proposal based on this technology to DOE in February 1976 in response to an RFP for high-Btu gas demonstration plants. A contract for the Phase I design and development, to be funded entirely by DOE, was signed by Conoco and DOE in May 1977. A program of test runs using U.S. eastern caking coals was initiated at Westfield in September 1977. EPRI joined the project as a cosponsor a month later. Because a high-Btu gas demonstration plant was proposed for Noble County, Ohio, shipments of Ohio No. 9 and Pittsburgh No. 8 coals were delivered to Westfield for the test program on design coals. The initial test program was halted in March 1978 without successful running of 100% U.S. eastern caking coals except by charging alternately with coke. However, in a subsequent test program from June to August 1978, a modification in the gasifier gave a better fuel bed and resulted in the successful gasification of 100% U.S. eastern caking coals.

Figure 2 BGC gasifier, as modified at Westfield, Scotland, for slagging operation.



In July 1978, a 96-hour test was run on sized (6–38 mm; 0.25–1.5 in) Pittsburgh No. 8 coal, including a period run at greater than design throughput. Later, a 48-hour run of sized (6–38 mm; 0.25–1.5 in) Ohio No. 9 coal was conducted. In each case, postrun inspection showed good internal and gasifier-bed conditions. A final 5-day run on Pittsburgh No. 8 coal was conducted in August 1978 with up to 23% fines in the coal feed. The last test (RP1186) was particularly important because modern, continuous-mining methods tend to produce as much as 50% fine coal (<6 mm; <0.25 in). Table 1, presenting data from actual tests with Pittsburgh No. 8 coal, compares operating results obtained with the dry-ash and slagging gasifiers at Westfield. The performance of the Lurgi dry-ash unit given in this table was not optimized, and some increase in throughput and decrease in steam consumption would probably be achieved on a modern unit. However, the table illustrates the significant improvements in performance of the slagger over the Lurgi dry-ash unit.

The originally proposed demonstration plant for producing 1.7 million normal cubic meters per day (60 million standard cubic feet per day) substitute natural gas (SNG) using three operating gasifiers has now been modified to use a single gasifier (plus one spare) to produce 0.57 million normal cubic meters per day (20 million standard cubic feet per day) SNG. DOE is expected to decide soon between this project proposed by Conoco and a project based on the COED-Cogas technology put forward by the Illinois Coal Gasification Group.

Following the successful gasification of U.S. eastern caking coals, EPRI and BGC agreed to a further program of tests at the Westfield unit. This program, which is planned

Table 1
OPERATING TEST RESULTS FOR LURGI AND BGC GASIFIERS

	Coal	Oxygen (t/t coal*)	Steam (t/t coal*)	Coal Feed Rate (kg coal*/h/m²)	Coal Feed Rate (lb coal*/h/ft²)	Gas Liquor Yield (kg/t coal*)	Gas Liquor Yield (lb/t coal*)	Gas Higher Heating Value (MJ/m³)	Gas Higher Heating Value (Btu/scf)	Run Duration (h)
urgi dry-ash asifier	Pittsburgh No. 8	0.70	5.10	709	145	2594	5718	10.65	286	48
GC slagging asifier	Pittsburgh No. 8	0.56	0.41	4254	870	172	380	13.26	356	88

*On a moisture- and ashfree basis.

for the summer of 1979, is aimed at the specific application of this gasification technology to power production systems. Several steady-state, turndown, and transient conditions will be tested to examine the ability of the unit to perform under the full variety of load changes that might be required of a gasification-based power plant that is operating in a utility power-generating network (RP1267).

Texaco entrained gasifier

For several years, Texaco has been developing a pressurized, single-stage, downflow, entrained gasifier fed by high-concentration coal in water slurries. A variety of U.S. coals have been tested at a 15-t/d pilot plant at Montebello, California (Figure 3). In the fall of 1978, a series of dynamic test runs was initiated on the unit under EPRI sponsorship (RP985-1). In these tests, the fuel gas is scrubbed clean of particulate matter and the H_2S is removed in a Selexol unit (a process licensed by Allied Chemical Corp.). In addition, atmospheric combustion tests on the clean fuel gas are performed by United Technologies Corp. on a modified combustion can from an FT-4 combustion turbine. This series of dynamic load-change tests is to be conducted for oxygen, air, and oxygen-enriched-air gasification under several process conditions, including different pressure levels.

The results of the initial runs with oxygen-blown coal in water slurries appeared to show that the quality and the heating value of the gas from the gasifier remained essentially unchanged over a wide range of operating conditions, including imposed transients. More-rigorous tests are planned to confirm the validity of this important preliminary result.

An additional preliminary result of great importance was that the particulate removal system was extremely efficient in reducing the particulate matter in the gas to a very low level, considerably below proposed EPA emissions standards.

In January 1978, a 150-t/d Texaco unit began operation at Ruhrchemie AG's plant in Oberhausen, Federal Republic of Germany. This project is sponsored by the West German Federal Ministry of Research and Technology (60%), Ruhrkohle AG, and Ruhrchemie. Test runs to date confirm the success of the tenfold scale-up from the Montebello pilot plant to the German unit. An additional development being tested on the Ruhrchemie unit is a waste heat boiler at the gasifier outlet. This equipment is particularly important for configuring an effi-

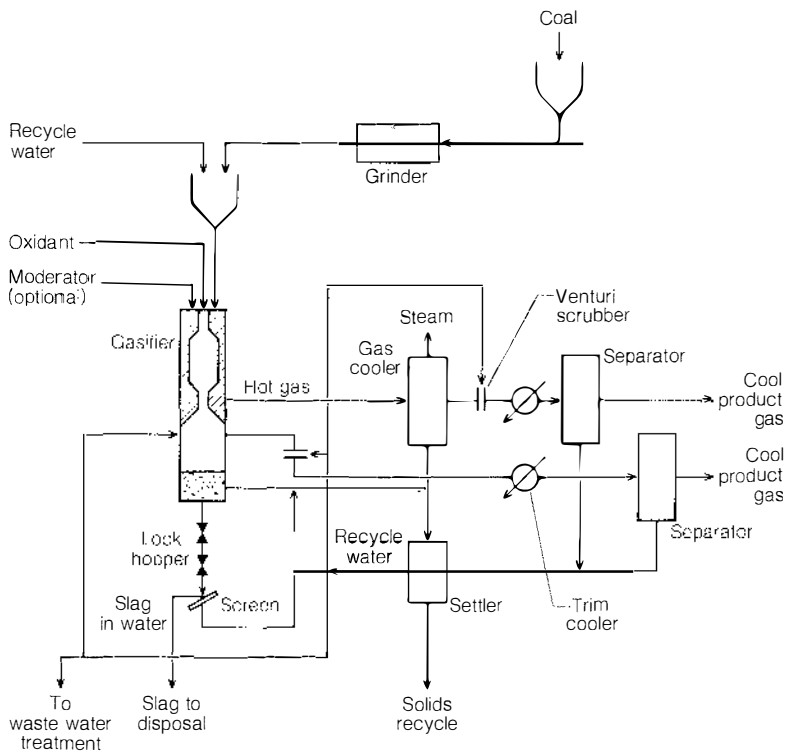


Figure 3 Process flow in the 15-t/d pilot-scale Texaco gasifier at Montebello, California.

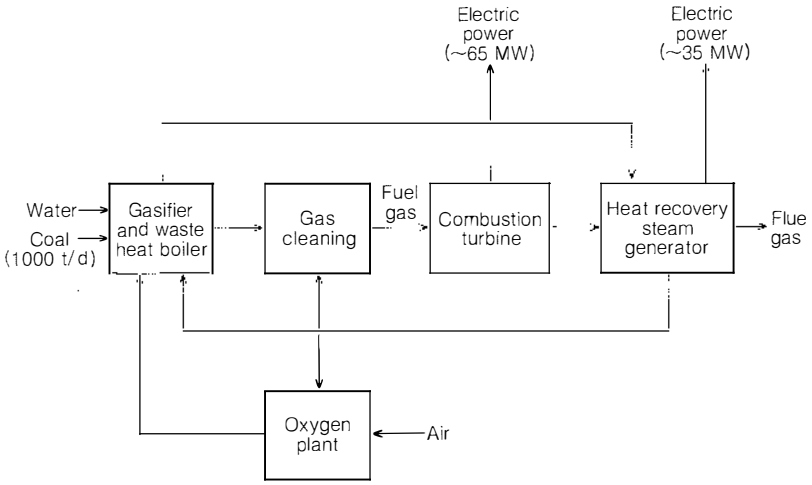
cient GCC power-generating plant.

Following this successful scale-up of the coal gasifier, Texaco and Southern California Edison Co. (SCE) have proposed a 100-MW integrated GCC demonstration plant to be located at SCE's Cool Water Station near Barstow, California (RP1459). Authorization for EPRI to participate with Texaco and SCE on an equal funding basis in the design of this plant was approved at the November 1978 meeting of the EPRI Board. The design phase is estimated to cost about $28 million. The total cost of the project, including design, construction, and initial operation, is currently estimated at about $300 million. The plan is for plant operation to start in 1983 (Figure 4).

The Texaco coal gasification technology is judged by EPRI to be the preferred choice for scale-up to full commercial-size demonstration modules. The gasifier has many desirable characteristics for integration with power systems—namely, simplicity (no moving parts), feedstock flexibility (all U.S. coals), minimum downstream processing (absence of tars), safety (water slurry), pressure operation compatible with the combustion turbine, and expected rapid response to load change. Further reasons for confidence in the additional sixfold scale-up to 1000 t/d proposed for the Texaco-SCE project are the advanced status of development, the demonstrated tenfold scalability of the pilot plant, and the strong similarity to Texaco residual oil partial-oxidation processes (of which Texaco has licensed more than 70 commercial units).

The 100-MW demonstration plant will comprise a commercial-size, 1000-t/d, oxygen-blown gasifier with associated heat exchange, particulate removal and recovery, and sulfur removal and recovery. The clean fuel gas will be fired in a commercial-size combustion turbine equipped with a heat recovery boiler.

Figure 4 Process flow in the proposed 100-MW gasification–combined-cycle demonstration plant to be funded by EPRI, Texaco, and Southern California Edison.



Future commercial-size plants of 500–1000 MW will consist of multiple trains of gasifiers and combustion turbines of the same size as the demonstration plant, with economies of scale resulting from larger common facilities for coal handling, steam raising, and gas cleanup.

Assuming the successful demonstration of the integrated GCC plant by 1985, commercial full-scale units based on this technology are projected to begin operation about 1990. *Program Manager: Neville Holt*

R&D Status Report
NUCLEAR POWER DIVISION

Milton Levenson, Director

URANIUM-FUELED SPECTRAL-SHIFT-CONTROLLED REACTORS

A mixture of light and heavy water is used as the moderator and coolant in a spectral-shift-controlled reactor (SSCR). The ratio of light to heavy water is varied to change the speed distribution (shift the spectrum) of the neutrons in the reactor core. Because the probability of neutron capture and fission varies with neutron speed, a measure of reactivity control with burnup is thus obtained. In an EPRI project, the uranium-fueled SSCR concept was evaluated.

LWRs operating on the once-through uranium fuel cycle have become the primary means of nuclear energy production in the United States and most of the rest of the world. Although the fast breeder reactor was assumed to be the eventual goal in nuclear development, its deployment has been delayed by a number of institutional and technical concerns, the most recent being the increased concern about nuclear weapons proliferation. Delay of the breeder option has caused increased awareness of the limited nature of uranium resources and has motivated the evaluation of alternative concepts for improving the efficiency of fuel utilization.

The SSCR is unique among the advanced converters being considered to fill this interim role because of its close relationship to the LWR. Because it is based on and built of PWR components, the SSCR may have the potential to be introduced sooner than other advanced converters. In addition, because of the low risk inherent in the concept (e.g., the SSCR can always be operated in the conventional boron poison control mode), prospects of rapid acceptance and widespread deployment could be enhanced.

In an EPRI-sponsored study, Combustion Engineering, Inc. (C–E) conducted an investigation into the potential resource savings, the economic motivation, and the technical feasibility of the SSCR, employing various uranium fuel cycles (RP978). This work complements a DOE-sponsored study to develop a conceptual design of a large SSCR that primarily uses thorium-based fuels. The EPRI program consisted of three major tasks: development and validation of analytic methods, evaluation of the resource requirements and economics of the uranium-fueled SSCR, and investigation of the potential for enhancing resource conservation and the economics of power generation through lattice optimization.

Excess reactivity in the SSCR is controlled through the use of variable moderating properties rather than through neutron absorption by control poisons. With heavy water (D_2O) replacing a portion of the light water (H_2O) in the SSCR, neutrons remain at resonant energies for a longer period and therefore have a higher probability of capture by the fertile component of the fuel. As the fuel depletes, the ratio of D_2O to H_2O in the moderator is reduced until, by end of cycle, the moderator is essentially pure light water. The productive utilization of the excess neutrons generated throughout the cycle results in fuel makeup requirements that are lower than those for the conventional PWR, since more fissile material is produced and subsequently burned in the SSCR during operation than in its poison-controlled counterpart.

Incorporation of spectral shift control can be accomplished with minor modifications to the nuclear steam supply system of the PWR. Modifications are generally restricted to ancillary components and subsystems that control the concentration of D_2O in the reactor coolant and that increase the fraction of D_2O in the mixture for the subsequent operating cycle. In addition, components and systems that carry D_2O are designed to minimize the loss of D_2O and the release of tritium to the environment. The D_2O upgrader is the only major plant system that is a unique addition to the PWR for spectral shift control. The separation of D_2O from H_2O in the upgrader is accomplished by multiple fractional distillations under vacuum. The upgrader unit is similar in design to units already in operation in the Canadian heavy water reactor program.

In order to generate accurate fuel-cycle data for the SSCR for comparison with previously analyzed poison-controlled fuel cycles, the analytic methods available for LWRs were extended and benchmarked for D_2O-moderated systems. To enable analysis of systems moderated by mixtures of light and heavy water, this task included the modification of C–E's lattice cell code, CEPAK. In addition, a procedure employing two-dimensional interpolating tables to represent D_2O and burnup-dependent cross sections was implemented for spatial diffusion calculations in the code PDQ.

Selected lattice experiments, which were performed by Babcock & Wilcox Co. in support of the original SSCR basic physics program developed in the early 1960s, were reanalyzed in this study with ENDF/B-IV cross-section data. Satisfactory agreement between calculated and experimental values of reactivity was obtained.

Three uranium fuel cycles were evaluated for the SSCR: the UO_2 once-through fuel cycle, the UO_2 fuel cycle with self-generated plutonium recycle (SGR), and the UO_2–^{233}U fuel cycle. For each of these fuel cycles, two-dimensional PDQ calculations were performed for several depletion cycles until interbatch neutron leakages and the variation of D_2O concentration with core burnup became relatively constant. A reactor model was then used to generate 30-yr mass flow data, from which fuel resource requirements and fuel cycle costs were obtained for each of the fuel cycles analyzed. In addition, core

physics parameters were calculated, and their impact on the safety and licensing aspects of the SSCR was assessed.

The U_3O_8 and separative work requirements of the SSCR are significantly fewer than those of the PWR because of improved neutron economy. Although the end-of-cycle fissile inventory for the two concepts is essentially the same, the higher conversion ratio during the SSCR cycle reduces the annual makeup requirements for a given energy extraction. The savings in 30-yr U_3O_8 requirements attributable to spectral shift control are 12% for the UO_2 once-through cycle and 22% for the SGR cycle. Similar savings in separative work are obtained by the use of spectral shift control.

The better fuel utilization of the SSCR is reflected in lower fuel-cycle costs. However, the capital costs of the SSCR are higher because of the D_2O inventory (~$54 million), the D_2O upgrader facility (~$10 million), and equipment modifications and additions to the plant auxiliary systems (~$16 million). These opposing cost trends result in total busbar power costs that are comparable with those of the PWR at uranium prices of about $175/kg ($80/lb); the potential for comparatively lower power costs increases as the price of uranium increases.

As part of the evaluation of the spectral shift concept, a lattice optimization study was performed for the UO_2 once-through and the UO_2 SGR cores. The objective of this study was to determine whether significant resource and/or economic savings could be achieved by lattice or fuel management optimization. Several parameters, including water-to-fuel ratio, number of in-core batches, fuel density, burnup, and range of D_2O concentrations, were varied to determine the effect on ore and separative work requirements and on total busbar power costs. This optimization showed that there is little incentive for changing the lattice from the conventional PWR configuration. For the UO_2 once-through cycle, modest improvements in U_3O_8 requirements (~8%) and in power costs (~1% for present U_3O_8 prices) can be achieved by modifying the lattice design; however, these modifications proved counterproductive when recycle was considered. For the SGR cycle, the benefits of lattice optimization are even smaller than those for the once-through cycle and require changes in the opposite direction from those for the once-through cycle.

An improved fuel management scheme that employs five in-core batches and extended fuel burnup (~50,000 MWd/t) was found to give significantly lower uranium requirements (~15%) and lower power costs (~2.5%) for the UO_2 once-through cycle without raising the questions of design feasibility that are associated with major lattice changes. However, extending the fuel burnup results in higher fuel resource requirements for the SGR core. Uranium ore and separative work savings are obtained for this core by the use of low fuel burnup and/or short operating cycles. Unfortunately, these strategies have an adverse effect on both reactor availability and power generation costs. *Project Manager: Ching-lu Lin; Program Manager: Bal Raj Sehgal*

IMPROVED METHOD FOR DETECTING CONDENSER LEAKS

Both fossil plants and nuclear plants have been plagued by the problem of locating leaks in steam condenser cooling tubes. Such leaks can introduce corroding chemicals into the steam system. In an EPRI project, a new tracer-gas method has been evolved that is more sensitive and effective in detecting leaks than methods that use foam, plastic film, or sonics as leak indicators.

Steam generator corrosion and tube denting can be caused by chemistry changes in the steam system, and this has reemphasized the need for better methods of isolating leaks in cooling-water tubes of condensers. Leaks between the tube and the tubesheet are difficult to detect with existing methods, and the thousands of tubes to be inspected during maintenance make leak location a time-consuming operation.

EPRI contracted with Science Applications, Inc. (SAI) of Rockville, Maryland, to develop and demonstrate a tracer-gas method of locating leaks in cooling-water tubes (Figure 1). Some work had been done with tracer gases to locate air inleakage to condensers, but tracer gases had not been used successfully for detecting leaks in the tube face or the tubes.

The presence and general area of a leak is usually determined by a prelocation method, such as condensed water conductivity. Other widely used methods are tests for silica, sodium, chlorides, and chemistry changes in the condensed water.

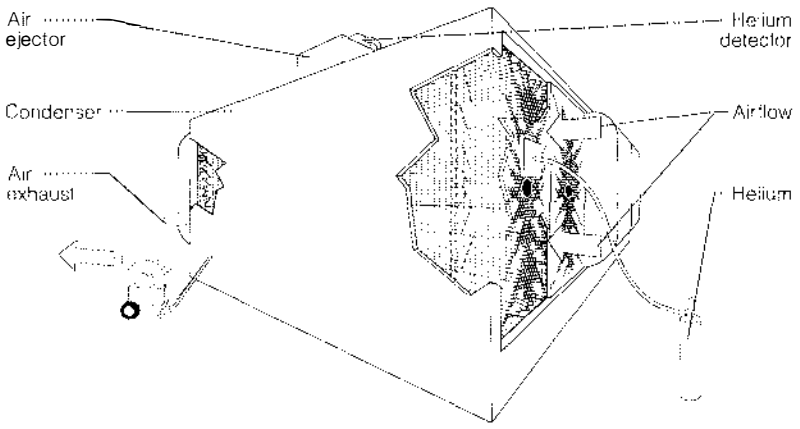


Figure 1 The tracer-gas method of leak detection in plant steam condensers.

A variety of methods are then used to find the exact location of the leak to permit repair or tube plugging. Most methods, including this tracer-gas method, create a vacuum on the steam side of the condenser and use this pressure differential for leak location. For example, when plastic film is placed on both ends of a tube, deformation or breaking of the plastic indicates that a leak is drawing air from the tube. Detergent foam, wet paper, or light pastes can be used instead of plastic film. Audio and ultrasonic detectors and even pressure gauges have also been used. However, despite general indication of leaks by the prelocation methods, it is not always possible to locate the leaks precisely enough to allow tube plugging within the time available for condenser maintenance (NP-481).

There are fundamental reasons why tracer-gas leak location has not been successful in the past. The waterbox areas are limited in size and access, and the buildup of background levels of tracer gas soon reduces the sensitivity of the system to an impractical level. Locating and isolating a single leaking tube is a difficult task, especially when a number of small leaks are present and when the amount of maintenance time available is limited by the expense of reduced power operation of the plant.

In the EPRI–SAI project, helium was used as the tracer gas (NP-912). Other tracer gases such as Freon are of course available, but for demonstration, helium has the advantage of being easily detectable in small amounts. Also, because helium is employed as a tracer gas in many other industrial applications, sensitive on-line measuring equipment is available off the shelf.

To reduce the background level of helium, SAI attached an exhaust fan with portable exhaust tubing to the waterbox at the end of the condenser opposite from the one where helium was to be released. This fan drew an airflow through the cooling-water tubes of the condenser. Air entered from the other end of the condenser, traveled down the tubes, and was exhausted by the fan to the outside area. This airflow provided a carrier for the helium releases and also swept the area to keep the background helium low.

To limit the helium to a known number of tubes, it was released in a plenum whose contact edge was sealed with a sponge-rubber-like material. A cloud of helium was released over the tube face and into the tubes to be tested. An air valve to the plenum was then opened, and the exhaust fan airflow drew the cloud of helium down the tubes and exhausted it to the outside. Leaks in tube-to-tubesheet joints or in the tubes themselves could be identified because the helium leaked to the vacuum on the steam side of the tubes and from there to the air ejectors, where the helium detectors were placed.

Use of the large plenum enabled the leak search to be limited to about 400 of the approximately 10,000 tubes subjected to the release. More precise localization was achieved by use of progressively smaller plena in subsequent releases. Eventually, helium was released down the single suspect tube to verify the leak.

With this method, measurement of the time delay from helium release to helium detection at the air ejector indicates the position of the leak in the tube when more than one leak is present (which often occurs with corrosion or vibration damage). Communication is maintained over sound-powered phones. A short delay indicates a leak in a tube-to-tubesheet joint or in a section of tube near the tube face. Longer delays after helium release indicate that the leak is farther down the tube toward the opposite tubesheet.

The method also seems suitable for sweeping major areas of the tube face without a plenum so that localized detection methods can be applied to major suspect areas rather than to each group of tubes in turn. In one plant with Freon detection equipment, leaks were located with this method by using Freon as the tracer gas. There are other gases that are even easier to detect than helium, but so far there is no indication that they are needed. The tracer-gas method is effective and can locate leaks smaller than those found by previous methods. It locates tube-to-tubesheet leaks, which appear to be almost impossible to detect by plastic film, wet paper, or other methods.

Before a plant uses the tracer-gas method, the interconnections and piping to and from the condensers and air ejectors should be reviewed. If a number of waterboxes are manifolded prior to air ejection, the method will be less sensitive because of greater mixing of the tracer gas with air and the escape of some gas via unmonitored exits. Also, air inleakage from the plant to the steam-side vacuum will reduce sensitivity. Since the tracer-gas method works equally well for locating air leaks, it probably pays to inspect for air leaks as part of the maintenance operation in the areas of valves, drains, seals, and flanges. Such leaks reduce turbine efficiency and have been difficult to locate because, unlike leaks of steam or water, they do not produce visible plumes or liquid drops. *Project Manager: Roy Swanson*

POOL SWELL IN MARK I CONTAINMENT PRESSURE SUPPRESSION SYSTEMS

Pool swell is the hydrodynamic phenomena produced by the discharge of air into a suppression pool of water and the resultant pool motion. Early in a hypothetical loss-of-coolant accident (LOCA), pool swell will induce significant loads on some BWR Mark I containment structures. The phenomena have therefore received attention from the BWR Mark I Containment Owners' Group, the Nuclear Regulatory Commission (NRC), and EPRI. The Mark I Owners' Group has initiated programs that focus on engineering and structural evaluations related to pool swell. The NRC is sponsoring both basic research at the University of California at Los Angeles and Massachusetts Institute of Technology and engineering tests at Lawrence Livermore Laboratory. EPRI-sponsored projects in this area have been an integral part of the Mark I Owners' Group program to further define the hydrodynamic phenomena and to assess structural loads.

Since June 1975, EPRI has performed experiments in scaled models of Mark I containments and has developed hydrodynamic computer codes to investigate pool swell. The three major areas of study are:

- Hydrodynamic analyses of pool swell (RP693-2)
- Modeling of transient compressible flow in manifolds (CSA 77-71A)
- Multiple downcomer pool-swell tests (RP693-1)

The predictive methods have been extended and the completed data base on multiple downcomers (NP-906) is being used for computer model validation.

The research to predict loads on a generic Mark I containment pressure suppression system during a postulated LOCA is a cooperative effort between Jaycor and Professor Paul Chambré of the University of California at Berkeley. Jaycor has developed a hydrodynamic pool-swell code that accounts for multiple downcomers, while Professor Chambré has developed a model for transient, compressible flow in the vent system manifold. By combining these two codes, several downcomer pairs and a common wetwell airspace can be modeled in conjunction with the transient manifold flow (Figure 2). This combined code will be referred to as a 2½-dimensional code and

will be used to predict the nonuniform pool swell along the torus. The manifold model describes the time-dependent airflow to each downcomer pair. This combined code was developed because structural response strongly depends on the nonsimultaneous pool-surface arrival at impacted structures.

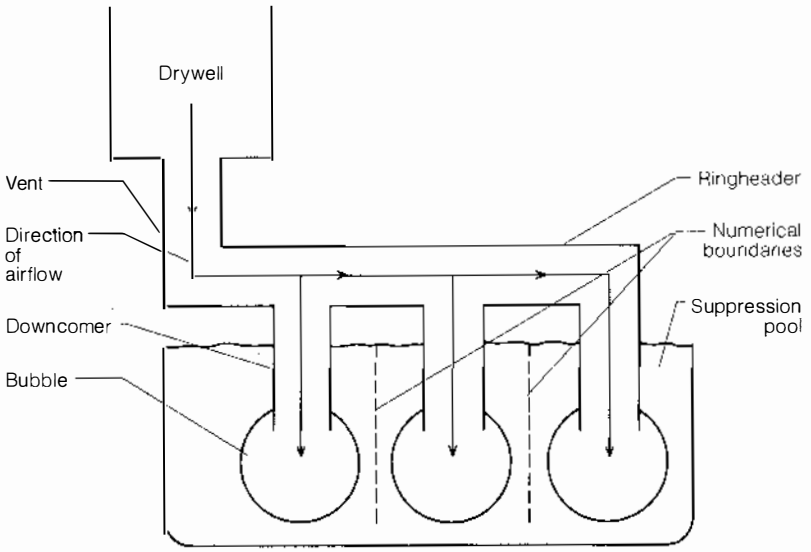
Multiple downcomer pool-swell tests, performed by SRI International, investigated at reduced scale (1:12) the multidimensional hydrodynamic effects during the early pool-swell phase in a scaled Mark I pressure suppression system following a postulated LOCA. As a result of these tests, the 3-dimensional pool-swell phenomena, wall pressure distributions, and loads were quantified (NP-906). The compiled data base is being used to validate the 2½-dimensional pool-swell computer code.

The test model consisted of 12 downcomer pairs connected to a ringheader and enclosed within a transparent right circular cylinder simulating a 90° torus sector without miter joints (Figure 3). This is the only large model in existence that permits full visualization and photography for quantification of 3-dimensional pool-surface effects.

The tests were conducted by rapidly pressurizing a simulated drywell, blowing air down through the vent system that connects the drywell to the wetwell, and recording the subsequent pool swell in response to the blowdown. The blowdown process was recorded by a high-speed movie camera, load cells, and pressure transducers. The load cells measured the forces on the simulated torus and the independently suspended ringheader. The pressure transducers measured the history of the drywell pressure, downcomer exit pressure, wetted boundary pressure in the lower half of the torus, and wetwell air space pressure. High-speed movies recorded hydrodynamic response of the water from both the front and the side. The sweep time of impact on the ringheader was also quantified from this film; the sweep time strongly affects the structural response of the ringheader.

The data base generated by the experimental series has been used by the Mark I Owners' Group and General Electric Co. to assist in application of their 2-dimensional test results to actual Mark I suppression pools. The 2½-dimensional computer code verification effort is using these data and should eventually provide additional assistance in resolving parameter sensitivity questions related to variations in actual plant designs. *Project Manager: Charles Sullivan*

Figure 2 Simulated airflow from the drywell to the suppression pool in a Mark I containment pressure suppression system. The drywell surrounds the reactor vessel and is connected to the suppression pool via the vents, ringheader, and downcomers. The boundaries between bubbles are assumed so that the pool can reasonably be simulated on a computer.



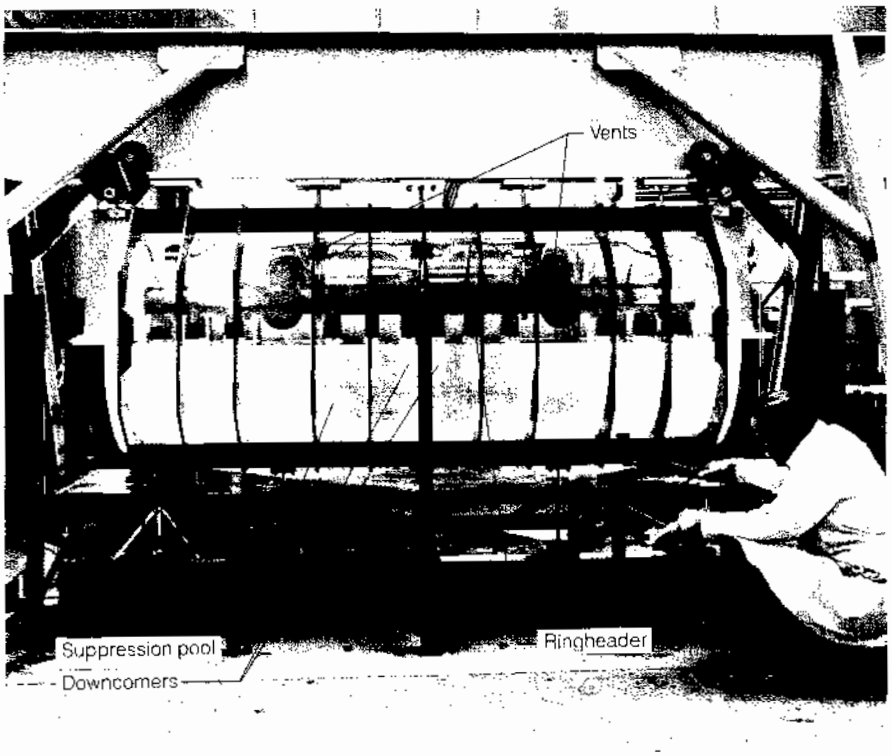


Figure 3 This 90° sector of a 1/12-scale Mark I suppression pool includes drywell, vents, ringheader, downcomers, and pool boundaries. A blowdown is simulated by discharging air through the two vents into the ringheader and down twelve pairs of downcomers. The structures above and below the model merely support it and the load cells.

R&D Status Report
ELECTRICAL SYSTEMS DIVISION

John J. Dougherty, Director

SUBSTATIONS

Field calibration system for CCVTs

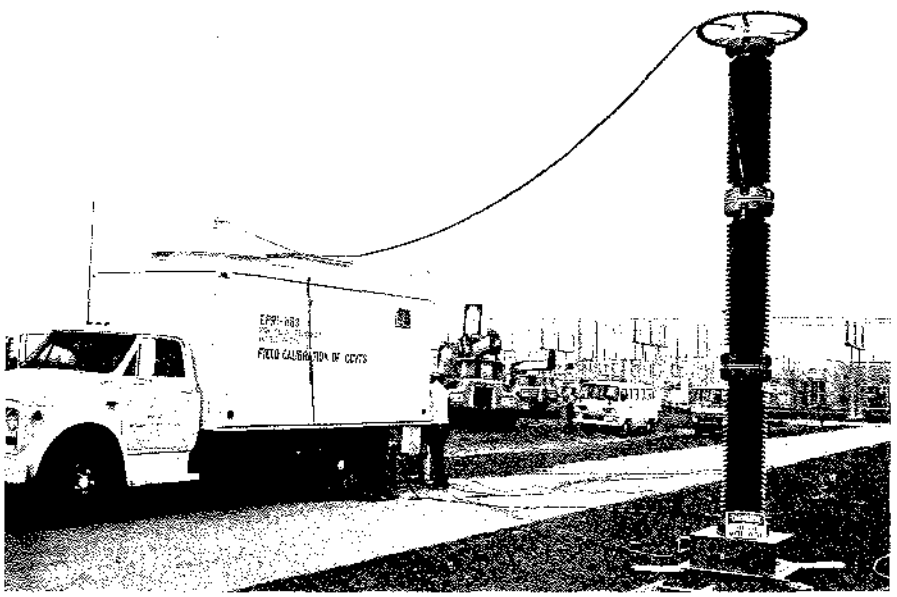
A field calibration system for coupling capacitor voltage transformers (CCVTs) of metering class is now available to utilities from the National Bureau of Standards (NBS), which developed the system under a contract with EPRI. The project (RP134), jointly sponsored by EPRI and NBS, was initiated in 1973 because utilities had doubts about the adequacy of CCVTs for energy-metering applications. The problem is that even if the CCVTs have acceptable accuracy on leaving the factory, very little is known about their long-term stability. Periodic calibration of the CCVTs seems to be an obvious solution, but calibrations with the required accuracy (0.05% or less) are difficult to make in the laboratory and even more difficult in the field. Consequently, few utilities use CCVTs in metering applications.

The accuracy targets for the calibration system were an amplitude error of 0.05% and an angle error of 0.3 mrad (1′) or less. The system had to be simple to operate, mobile, and applicable (with minimal modifications) to UHV levels. It also had to be possible both to connect the system directly to the energized high-voltage bus system without risk of flashover, and to set the system up in a reasonably short time.

Prior to field trials, the calibration system underwent thorough laboratory testing, which verified that the design goals for the equipment had been met. In one field test of the calibration system (Figure 1) at a 500-kV substation, three out of six metering-class CCVT units were found to have errors exceeding the accepted 0.3%, 4.6 mrad (16′) limits. These units had been in operation for four years. They had not been used for energy metering, and the manufacturer had earlier identified design defects in some of the units. However, the worst error measured (2.4%) was even beyond the normal error limit for relaying purposes.

In another field test, six newly installed cascade potential transformers were shown to have almost exactly the same accuracy as they had had before leaving the factory. This proves that the mobile calibration system by itself is useful for making accurate field calibrations. Too few CCVT performance data were obtained in this project to justify any recommendation of calibration intervals. It would seem prudent though to calibrate CCVTs periodically, at least until the long-term behavior of the CCVT is better known. This is particularly important if the CCVTs are used for metering purposes. *Project Manager: Stig Nilsson*

Figure 1 The CCVT mobile unit is shown during a field test at a 500/230-kV substation. The calibration system is used to define the error of the reference voltage divider, which is then used to calibrate the operating CCVTs. The reference divider is calibrated with a 100-kV source inside the truck.



Calibration Service Available

Under an agreement recently completed with EPRI, the National Bureau of Standards (NBS) will provide on-site field calibration of CCVTs at a reasonable cost, using the mobile unit furnished by EPRI. Utilities interested in this service should contact David Hillhouse at NBS, (301) 921-3121.

Acoustic detection of partial discharges in power transformers

It is well known that electrical insulating materials are degraded by the action of partial discharges. This degradation can lead to eventual failure of the insulation and eventual loss of equipment. In some situations, the loss can be of a catastrophic nature. Because of this, the industry mounted an effort to develop a method of detecting this degradation phenomenon.

However, the only techniques applicable to operating transformers in the field involve the analysis of gas and oil samples drawn from the units. Although these approaches show the probable existence of partial discharges, the information tends to be somewhat historic because the volume of gas evolved by such a fault is small compared with the volume of oil in a transformer. This makes it difficult to determine the condition of the apparatus at the time of discharge.

A project with McGraw-Edison Co. was designed to develop techniques and prototype instrumentation for the detection of partial discharges in operating transformers and to present the data in real time (RP426). In order to make the information as useful as possible, the geometric location of discharge sources had to be determined. Then the severity of a particular discharge could be compared with the magnitude of a partial discharge source and its location within a transformer.

Previous experience at McGraw-Edison showed that the high-frequency (ultrasonic) perturbations produced by partial discharges could be detected by using acoustic emission techniques. Since the acquired data could be manipulated in many ways, it seemed possible to develop an approach that would overcome some of the problems inherent in the conventional ultrasonic methods used for partial discharge detection in factory environments.

Using this approach it was found that partial discharges had a telltale frequency around 150 kHz. Many other noises were detected in the transformers, the most surprising of which was an emission at approximately 50 kHz. This was found to emanate from the transformer core and was related to the properties of the magnetic material itself (core steel). Although the actual mechanism has not been positively identified, it is suggested that this emission is associated with the "flipping" of magnetic domains, as observed in the Barkhausen effect.

Partial discharge signals can be separated from others by using frequency filters or signal-to-noise ratio (S/R) discriminators. For maximum selectivity, both devices were employed. Tests were successfully carried out on power transformers both in the factory environment (where it was possible to cross-check results with other tests) and in substations of a cooperating utility, where the techniques were easily applied.

The geometric location of a source was determined by measuring the propagation time delay between two acoustic emission sensor locations. Several methods were used for this purpose, but the most successful was the well-developed signal-averaging technique used for improvement of S/R. When a trigger signal is formed from the data arriving at the sensor closest to the source, the signal averaging of data at the farthest sensor enables the S/R to be increased and the time delay to be readily obtained. In order for this information to be dealt with easily in the field, a calculation method was developed that does not require complex mathematical manipulation. An iterative solution was devised that requires the use of several sensor locations, from which simple arithmetic calculations are made.

Two simplified prototype instruments have been manufactured and tested in the laboratory. These demonstrate that the instrumentation required to carry out this type of work need not be complicated or expensive.

During this project, several areas were identified that require further study if these techniques are to be used to their fullest advantage. The effort is essentially laboratory-oriented and associated with such phenomena as the variation of the propagation velocity in transformer oil caused by various parameters, the attenuation effects of transformer materials, and the characterization of the signals from specific transformer faults. *Project Manager: Ed Norton*

UNDERGROUND TRANSMISSION

High-ampacity potheads

In the final report for RP7817, it was concluded that a very large increase in ampacities for potheads may be obtained by using cables with hollow-core conductor construction. This is because forced circulation of the core oil can remove a substantial part of the heat generated in the conductor.

Because of the thermal conductivity of the conductor, a significant amount of the heat developed in the cable can be carried away from the hot spot zone of the conductor through the pothead in the axial (usually vertical) direction. This axial heat flow is governed by the axial temperature gradients along the conductor and may remove up to 50% of the heat generated when the pothead is short and the conductor cross section is large.

For capacitor-graded potheads rated 230 kV and above and where porcelain length is substantial, only hollow-core conductor construction with forced circulation of core oil is likely to accommodate very high ampacities. In a new cable installation, the additional cost required for use of hollow-core conductor cable at the terminations should not be excessive. However, in most existing pipe-type cable systems, the changeout of the cable would be expensive between the trifurcation joints and the potheads.

For pipe-type cable systems rated 161 kV and below, it may be possible to obtain the required ampacity gains without the use of hollow-core conductor cable by exploiting the heat sink effect of axial heat flow. Because of the shorter lengths of 69-kV potheads, a substantial increase in ampacities may be obtained by using designs that amplify the heat sink effect. It is believed that this effect will make it possible to satisfy the required ampacity increases in a majority of existing 69-kV installations.

To explore the above suppositions, a project was initiated in July 1977 with G&W Electric Specialty Co. (RP7857). This 2½-year project will investigate a variety of schemes for increasing forced-cooled ampacities of non-capacitor-graded, 69–161-kV potheads without the use of hollow-core cable conductor. The cooling systems developed will be such that they can be retrofitted in existing terminals. A further phase of the project will use computer synthesis to assess a variety of cooling systems applicable to capacitor-graded potheads rated 230–500 kV. *Project Manager: John Shimshock*

Improved trenching operations

Because the operations associated with cable installation can account for 50% of overall system cost, Bechtel Corp. was contracted to find a more cost-effective system for trenching (RP7870). A system was proposed for use in urban and suburban environments. Evaluations were made of equipment used in all types of civil-engineering and construction operations and also of new equipment being developed for these and other purposes. Bechtel recommended short-term procedures to reduce installation cost, suggested long-term improvements in new equipment, and recommended modifications for conventional equipment and scheduling operations.

One of the most significant characteristics of underground cable placement is the sequential nature of trenching and backfill. Improvements to one specific element of the overall operation often have a strong impact on those preceding and following it. Hence, improvement in any one element does not always improve the overall installation. All operations must be favorably affected to achieve any appreciable cost reduction.

In the final report for this project, a reference installation along a specified course was compared with an installation using equipment still in the conceptual design stage. The latter operation—which took ad-

vantage of water-jet pavement cutters, unitized shoring systems, and specialized trenching equipment—was faster and less expensive than the reference operation. Most of the cost saving resulted from shorter installation time, which was effected by the use of new and improved equipment. However, the environmental impacts of both cases were similar. Except in specialized circumstances, construction activity did not produce unacceptable environmental effects in the view of regulatory agencies.

A continuous installation system (also described by Bechtel) using equipment requiring additional engineering and product development could further reduce costs and improve schedules. This system would employ an in-trench excavator, unitized collapsible shoring, traveling gantries, an above-ground welding platform, and an in-trench compactor in a continuous operation.

The conclusion of this study showed that further work was needed to produce a more detailed cost and schedule analysis and to further develop a continuous installation system for urban and suburban regions. The final report (EL-969) is in the process of publication and should be released in early 1979. *Project Manager: Thomas Rodenbaugh*

DISTRIBUTION

Fault current analysis

In spite of attempts to operate their systems with 100% reliability, distribution engineers are still faced with the problem of coping with faults. To give them a better understanding of the electrical characteristics of faults, EPRI has initiated a project on distribution fault current analysis (RP1209). The first objective of this three-year project, being performed by Power Technologies, Inc., is to compile data on the electrical characteristics of faults as they are actually experienced on primary distribution systems.

Since each fault is necessarily followed by reenergization of the load, a second objective is to investigate the characteristics of cold-load pickup. This is a subject that is much talked about but for which data are scattered and incomplete.

Results of this project will give distribution engineers a comprehensive knowledge of how voltages and currents change during faults and what to expect of currents during the reenergization of the interrupted load. They will then be able to make more efficient use of properly rated equipment, specify relay settings with greater confidence, and restore load more rapidly.

The project has three major phases: instrument acquisition and installation, data gathering on utility systems, and data analysis. In the first phase, 54 Macrodyne recorders, modified to fit the specific needs of this project, will be purchased. These have a frequency response of 10 kHz and thus will be able to capture transient as well as steady-state voltages and currents. Using a unique, variable-rate recording scheme, fault currents and phase voltages during the fault will be sensed at the substation bus for the full fault duration and reclosing cycle. These values will be digitized and recorded on cassette tapes for future computer processing.

Thirteen electric utilities have agreed to install the recorders in distribution substations. The utilities and the substations were selected to provide variety in terms of condition variables, including geography, type of load, voltage, weather, and historical fault rate.

In addition to installing the recorders at their own expense, the utilities will supply the contractor with all necessary data to fully characterize their systems. They will also supply as many data as possible for each recorded fault event, which will allow the contractor to perform the necessary calculations and statistical analyses.

During the second phase of the project, data will be gathered for two years, during which time the utilities will replace data tapes monthly. As noted earlier, the voltage and current during each fault, including reclosures, will be recorded. Cold-load pickup current will be fully recorded through the transient period and then sampled either until it decays to a preset level or for 20 minutes.

In the third phase of the project—the data analysis—each recorded fault will be compared with the calculated fault current and the apparent fault impedance will be determined. With these data, correlations will be made to relate such variables as voltage, cause, kind of fault, and geographic area. Calculation of phase voltages at the point of fault will also be an important result of the analysis.

For cold-load pickups, parameters to be characterized include transient peak current and its frequency and peak 60-Hz current and its rate of decay. Correlations will be made between the interruption duration, the 60-Hz current, and the rate of current decay.

With the completion of this project, it is expected the final report will become a standard reference book for distribution engineers. *Project Manager: Herbert Songster*

Recycling fly ash

Coal-burning power plants discharge great mounds or ponds of waste in the form of fly ash and slag, but because there is little demand for it, utilities are faced with a growing disposal problem. The consumption of coal in 1977 at one plant was 600,000 tons, and the process produced 72,000 tons of fly ash. The utility was able to give away or sell only 22,000 tons of the ash. With its own property filled with the prior years' accumulation of ash, new disposal sites had to be found. Old quarries, marshland fill, and other sites were investigated, but none offered a permanent solution.

Few uses have been found for waste fly ash. It is used in highway construction as an aggregate for concrete, on winter roads as cinder, in cinder block manufacturing, and as a landfill. The National Ash Association reports that new and expanded markets have been found for only 16% of the total production in the United States.

EPRI has initiated a project to explore the characteristics of fly ash in a crystalline state, which might be useful as a structural material as well as an insulator (RP1210). Partially crystallized fly ash was encountered during another project while developing a process for forming utility poles (RP851). Samples showed that it was much stronger than amorphous glass ceramic and had good insulation characteristics. Some trace ingredients in the fly ash apparently served as nucleating agents to start crystal formation after the fly ash had been melted, poured into molds, and cooled.

In the laboratory study, fully crystallized fly ash samples have been produced by the addition of various known nucleating agents, followed by a curing cycle of time and temperature most suitable to crystalline growth. Early analysis by X-ray diffraction shows the major crystalline phases to be anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$) and diopside ($CaO \cdot MgO \cdot 2SiO_2$). Alumina will be added to the fly ash in an attempt to introduce a mullite ($3Al_2O_3 \cdot 2SiO_2$) crystal phase in the crystallized fly ash. If successful, this addition should improve the mechanical and thermal properties of the material. If the anticipated properties are confirmed by electrical tests, crystallized fly ash may be substituted as a low-cost material for insulation, structural supports, or a combination of these.

Not long ago, Russia developed a similar material, Slag Sital, which is suitable for comparison. It is made from blast furnace slag that is high in calcia and silica. Fly ash contains alumina in addition to calcia and silica. Slag Sital is being used in highly abrasion resistant floor and wall tile and in electrical

insulators. Comparisons of these two materials will be continued throughout this project.

Fly ash may yet prove to be a valuable and usable resource to utilities, which produce the bulk of it, and to other industries. *Project Manager: Robert Tackaberry*

Insulating oil for electrical applications

There is a strong possibility that demand for the traditional naphthenic transformer oils will exceed supply in the mid-1980s. Production of transformers and other equipment (and hence electrical load growth) may be curtailed if alternative insulating fluids are unavailable at that time. A project to evaluate alternative fluids was recently completed by General Electric Co. (RP562).

Transformer fluids that have all or nearly all the necessary properties can be produced from the more plentiful paraffinic crudes. Not all experimental oil samples examined met the requirements in the ASTM/ANSI standard for fresh oils, but it appears that with careful refining, oils can be produced that do meet the standard at usual ambient and operating temperatures. The electrical, physical, and chemical characteristics of paraffinic oils also appeared to be comparable with those of naphthenic oils in tests with conditions more closely simulating those in actual electrical equipment. The oils were characterized by several analytic techniques, and it was found that the compositions of naphthenic and paraffinic oils differ primarily in the amounts of linear paraffinic hydrocarbons present.

The aging behavior of paraffinic oils was also comparable in accelerated transformer-aging tests, in oxidation tests, and in small-scale accelerated system-aging tests. These aging studies also resulted in comparisons of the aging behavior of transformers and of the oil in the transformers; the oil in bench-scale tests was compared with that in actual transformers. It appears that evaluation of oil aging can be done without resorting to actual aging in apparatus.

The low-temperature behavior of paraffinic oils, however, is different from that of naphthenic oils. Unless heavily dewaxed, paraffinic oils are too thick to flow. The dielectric strength of wax-containing oils appears to be comparable with that of naphthenic oils except when cracks or voids form. Appropriate viscosities (at least, at all but the lowest shear rates) can usually be produced by deep dewaxing, addition of flow modifiers, blending with other oils, or some combination of the three. Flow and heat transfer are then optimized, and the possibility of crack and void formation is minimized.

This evaluation of experimental oils indicates that paraffinic transformer oils as a class can provide useful supplements or replacements for naphthenic oils. Depending on the market price of naphthenic oils in the future, paraffinic oils may or may not be competitive. Any oil produced commercially in the future will have to be evaluated on its own merits. The applications suitable for a given oil will also require individual evaluation because of the variation in the low-temperature behavior of paraffinic oils.
Project Manager: Ed Norton

R&D Status Report
ENERGY ANALYSIS AND ENVIRONMENT DIVISION

René Malès, Director

INTEGRATED ASSESSMENT

The objective of the Integrated Assessment Program is to assess the effect of electricity-generating technologies on the environment and, conversely, the effect of environmental regulations on these technologies. The assessments should benefit three groups: the electric utility industry, which has to contend with the environmental impacts of a given technology and choose alternatives; the R&D community, which has to design technologies to minimize environmental concerns and impacts; and the policy-making community, which has to examine information on environmental impacts of various technologies before setting policy.

One goal of the program is to develop frameworks for assessing various technologies, including those for pollution control. The use of cost-benefit analysis as an evaluation tool is being examined (RP755-1). The problems of applying cost-benefit analysis to environmental problems arise from the lack of well-defined damage functions and the need to incorporate the factor of uncertainty. In one project, a model developed for the Environmental Protection Agency will be evaluated for its applicability for assessing the impacts of environmental policy on the electric utility industry (RP1318). This model simulates the operation of a utility system and examines the interaction between environmental regulations, environmental quality, and utility systems. The model is being applied to the Tennessee Valley Authority system, where alternative potential regulations for control of fine particulates will be considered. In the future, environmental factors will be integrated into many energy and economic models under development and study by EPRI's Energy Analysis Department. A workshop was recently held to outline a research program for integration of environmental factors in other models (WS-78-95). Other approaches to be studied in this program include risk-benefit analysis and methods that incorporate public perception of environmental impacts and risks.

Another goal of the Integrated Assessment Program is the evaluation of existing environmental data bases, which have been used to establish environmental policy. An example of the data bases being examined are those that have been used in cross-sectional studies of the relationship between mortality and air pollution (RP1316). There are several other types of data bases that need to be assessed. For example, data on the emissions associated with certain technologies need to be evaluated. Also, information on the costs of operating these technologies, particularly with new and untried emissions control systems, needs to be reviewed.

A further goal is to identify and obtain information needed to achieve the overall objective of a particular program. In a project designed to estimate the damage to materials caused by air pollution, it was found that existing estimates did not specify the materials that were exposed to air pollution, the levels of air pollution to which the materials were exposed, or the importance or value of the materials (RP1004). This lack of information makes it impossible to place any confidence in the estimates, and steps will be taken to complete the data.

Another project will provide methods for estimating socioeconomic impacts associated with power plant construction and operation (RP1226). The absence of a comprehensive data base makes it difficult, if not impossible, to validate these estimation methods. EPRI plans to establish a data base that is detailed enough to validate existing methods for estimating socioeconomic impacts and to suggest alternative methods.

A study is taking place to perfect a methodology for assessing the value and importance the public attaches to good visibility in a given area (RP775-2). Although methods exist for estimating the value of visibility, there is still a need to apply the methods to situations of differing visibility and of related conditions. Moreover, there is a need to improve the reliability of such value estimates.

A further project associated with the goal of fulfilling information needs has determined the environmental impacts associated with fuel transport (TPS77-661). Previously, existing literature had been incomplete and unreliable.

EPRI will continue research in the above areas as well as increase its attention to esthetic impacts, such as those of power plants. Specific projects will provide environmental evaluations of conceptual technologies and will suggest ways in which potential environmental impacts could be mitigated early in the design stage of these technologies. Monitoring procedures will be defined at demonstration and pilot facilities to allow more-precise estimates of the environmental impacts associated with given technologies. A study was recently completed that assesses the environmental impact of two solar technologies (RP551-2), and similar studies are planned for a gasification technology (TPS77-710) and energy storage systems (RP1317). Other technologies will be considered in the future.

The Integrated Assessment Program is also considering generic siting issues for various technologies. One study is developing methods by which sites can be readily evaluated environmentally for a given technology (TPS77-710). A comparison is being made between the environmental impacts of dispersed coal-burning power plants and those of concentrated plants (RP1114). Four 550-MW coal-burning plants at different sites in the same region were compared with four units at a common site. Generic siting issues that may be examined in the future are energy centers, highly dispersed siting, determination of the resource capacity of an area, cogeneration, and siting models.

In an investigation of the impact of environmental regulations on the electric utility

industry, a case study of the proposed Kaiparowits power plant was carried out to determine what lessons could be learned by the utility industry from this example (TPS77-711). In a second study, the effects on the industry of many new and proposed NO_x regulations will be assessed, and suggestions will be made as to how the industry should respond (RP1375). In a new project, existing computer models will be applied to determine the impacts on the utility industry of alternative regulations for respirable suspended particles (RP1318). The impacts on the industry of alternative economic instruments for achieving environmental goals will be examined in another study (RP1419). These instruments include emissions charges and market procedures for allocating emissions quotas under the prevention of significant deterioration and nonattainment provisions of the Clean Air Act Amendments of 1977.

A further area to be investigated is the environmental and socioeconomic consequences of an electricity shortfall (RP1374). A workshop was held on this topic (WS-77-24), and a study to plan a research program is near completion (TPS76-652). *Program Manager: Ronald Wyzga*

ELECTRIC UTILITY RATE DESIGN STUDY

As part of the Electric Utility Rate Design Study (EURDS), advisory groups, consultants, and EPRI staff have produced approximately 60 research reports on various aspects of load management (RP434). This nationwide effort was in response to a request by the National Association of Regulatory Utility Commissioners (NARUC) to examine ways of controlling the growth in peak demand and its impact on electricity prices. Additional research on time-of-use rates and load controls continued in 1978. This work is organized into four major topics: (I) costing, rate design, and elasticity, (II) load controls and equipment for using off-peak energy, (III) customer response, and (IV) cost-benefit analysis. Topic II is the subject of the first report to be completed in the 1978–1979 phase of the study.

The report *Load Controls and Equipment for Using Off-Peak Energy* (EURDS Report 65), describes and analyzes equipment used with time-of-use rates and load controls. In addition, it evaluates 13 established or experimental utility load management programs that incorporate this type of equipment and 3 two-way communication systems. Arthur D. Little, Inc. (ADL) was the consultant for this research and worked closely with an advisory group made up of experts from utilities and regulatory commissions. ADL was active in the 1976–1977 phase of the Rate Design Study and contributed consultant reports on load management equipment and programs. These included *Topic 7: Metering and Communication Systems; Topic 8: The Utilization of Off-Peak Electricity; Topic 9: Mechanical Controls and Penalty Pricing* (bound in one volume as EURDS Report 5) and *Summary of Utility Load Management Programs* (EURDS Report 63).

Most utilities in the United States and Canada are actively engaged in load management and energy conservation projects of one kind or another. Demonstrations of load management equipment, in particular, are being sponsored by utilities as well as by DOE and EPRI. As the number of such programs has grown, efforts have been made to coordinate this work and to report progress. National and regional utility associations have set up special committees or used existing groups to facilitate the exchange of information on experiments, demonstrations, and experiences (e.g., the Load Research Committee of the Association of Edison Illuminating Companies and the Thermal Energy Task Force of the Edison Electric Institute). Universities and government energy agencies have conducted workshops and seminars to explore current activities and accomplishments as well as to encourage and plan future research, development, and demonstration.

The ADL research for the NARUC-sponsored Rate Design Study investigates 16 representative projects of three types: load management activities (10 utilities), individual residential thermal-storage experiments (3 utilities), and two-way utility communication systems (3 manufacturers).

For the 10 utilities that are conducting load management programs, several aspects are discussed by ADL.

- The general nature of the program and specific program details (e.g., number of customers, type of incentive, hours of operation)
- Assessment of equipment performance by the utility and participating customers
- Equipment characteristics (e.g., physical dimensions, electrical parameters, mode of operation)
- Benefits (potential impact on demand growth and load shifting)
- Costs (capital and operating costs, as available)

Three utilities analyzed by ADL have established individual residential thermal-storage experiments, typically involving a single house with a reservoir for storing hot water, cold water, or ice. These are essentially proof-of-concept tests, as opposed to large-scale load management programs. The information for these three experiments came solely from the host utilities and is less extensive than for the 10 load management program write-ups.

The three communication systems described by ADL focus on new two-way systems. These are designed for use in load management, remote meter reading, and automation of distribution systems. The communication systems include two that use the distribution system power lines (ASEP, by American Science and Engineering, Inc., and AMRAC, by General Electric Co.) and one that employs telephone lines for signal propagation (DARCOM, by Farinon, Inc.). Each of the three analyses includes a functional description of communication system operations, characteristics of major system components, and cost data for these components. For these systems, data on actual utility experience with the equipment were not available, and only prototype data and the manufacturers' specifications were reported.

The 10 load management programs are discussed below in detail. The ADL report should be consulted for more details.

Two basic categories of load management are described in the ADL report: demand control, where demand (kW) is reduced at particular times of day; and load shifting, where energy (kWh) consumption is shifted to off-peak hours. When managed by utilities, demand control is essentially load shedding and is viewed as a substitute for providing power. However, demand control can be performed by either the utility or the customer.

Load shifting implies that loads are removed from peak periods (when the cost per kilowatthour generated is relatively high) but added back during off-peak periods (when generating costs are lower). Load shifting is generally associated with energy storage in one form or another on the customer's premises, while demand control usually does not require storage equipment per se.

Demand control

Table 1 lists the utilities studied by ADL that practice demand control, the types of energy-using devices under control, the number of devices under control, and the type of communication system used by the

Table 1
DEMAND CONTROL PROGRAMS

Utility	Equipment Controlled	Number of Units Controlled	Control Method
Arkansas Power & Light Co.	Residential central air conditioners	16,500	Radio
Buckeye Power, Inc.	Residential water heaters	37,000	Radio
Cobb County Rural Electric Membership Corp.	Residential central air conditioners Residential water heaters	12,000 2,000	Radio
Elkhorn Rural Public Power District	Irrigation pump motors	120 (8,625 Hp)	Radio
Mississippi Power & Light Co.	Residential air conditioners Residential water heaters	125 125	Ripple system* Ripple system*
Ohio Edison Co.	Residential water heaters and electric clothes dryers	1,500	Interlock

*A ripple system is a low-frequency communication system, usually employed in a one-way mode, that sends signals over subtransmission or distribution power lines to receivers in customers' residences.

Table 2
LOAD-SHIFTING PROGRAMS

Utility	Equipment Controlled	Number of Units Controlled	Control Method
American Electric Power Co., Inc.	Thermal-storage water heaters Thermal-storage space heaters	72 72	Time switch Time switch
Central Vermont Public Service Corp.	Conventional water heaters Thermal-storage space heaters	24,100 130	Time switch Ripple system
Green Mountain Power Corp.	Conventional water heaters Thermal-storage space heaters	300 11	Ripple system Time switch
Kentucky Utilities Co.	Conventional water heaters	35,000	Time switch

utility to reduce peak demand. In brief, the utility accomplishes demand control of air conditioning by cycling only the compressor of a residential central air conditioning system. A typical cycle would be 20 minutes on, 20 minutes off, for as many hours as necessary on a high-demand day during the peak season. The air-circulating fan continues to run steadily during cycling, thereby minimizing household discomfort.

Residential water heaters typically have two heating elements, an upper and a lower unit. Some utilities control only the lower element, leaving the upper unit free to draw power as needed. Other utilities, like Buckeye Power, Inc., control both units. The former mode is appropriate for frequently controlled operations—e.g., those controlled on a daily basis. Buckeye Power chose the latter because it needs to control loads infrequently, on the order of 18–24 times per winter. Ohio Edison Co. uses a special demand-limiting device known as an interlock. This control prohibits the simultaneous use of two (customer-chosen) appliances. For example, an interlock can be used to prevent the operation of a water heater whenever an electric clothes dryer is running.

Load shifting

Load shifting can be accomplished by adding control devices to certain types of equipment, but more commonly it involves substituting a different type of equipment to accomplish the same purpose. As an example of the former, some utilities install clock-controlled switches on large conventional water heaters; this permits power to be drawn only in off-peak periods. A typical example of the latter case is when a homeowner replaces an outmoded fossil-fueled furnace with a new electric thermal-storage unit; this kind of furnace draws power exclusively in off-peak periods.

Table 2 summarizes the load-shifting systems employed by the utilities that ADL analyzed. The table lists three kinds of equipment (conventional residential water heaters, thermal-storage water heaters, and thermal-storage space heaters), as well as two methods of control (time switch and ripple system). Multiple methods of load management (thermal-storage equipment and controls) are frequently used in the same program.

Thermal-storage water heaters are better insulated than units typically found in homes today, are generally larger, and have more-sophisticated control systems. Installation is comparable with that of conventional water heaters in terms of cost. Space heating can be accomplished either by a centralized heat source in combination with a distribution system or by dispersed heat sources. Thermal-storage heating units are available for both types of installation. Several manufacturers now offer room-sized storage units, suitable for dispersed heating systems. Units of this type have proved satisfactory for Central Vermont Public Service Corp. (CVPS). Large centralized-storage heating systems have been tested (and are still under study) on selected utilities of the American Electric Power Co., Inc. (AEP). These units have a ceramic core and use a standard forced-air distribution system. Green Mountain Power Corp. (GMP) has also tested centralized-storage units. In GMP's case, however, the storage medium is water.

Load control in earlier systems used time switches to interrupt service to selected loads, such as the water heater. Such an approach is limited by the need to anticipate fixed settings and by the lack of customer control. Newer systems (e.g., ripple, high-frequency, radio) offer alternative techniques for influencing loads according to

those patterns. A clock-controlled switch with heavy-duty contacts (time switch) is employed by both AEP and Kentucky Utilities Co. (KU) for controlling thermal-storage devices. AEP uses switches with a built-in reserve capability, which maintains timing through outages; KU uses simpler but cheaper switches and has them reset by meter readers after outages. The other two utilities (CVPS and GMP) also use time switches, but generally only in areas where their ripple control signals are unavailable.

Preliminary results from the 10 load management experimental programs indicate the following.

- Customer acceptance of all programs has generally been excellent.
- Equipment performance, including control systems and thermal-storage devices, has generally been satisfactory.
- Five of the seven utilities with demand control programs plan to expand them in terms of the number of participants.
- Three utilities are pleased with their controlled water heater programs and continue to add customers.

One of the interesting findings of ADL's study is that some utilities (notably Buckeye Power and Cobb County Rural Electric Membership Corp.) have been able to explain the collective financial benefits of demand control to their customers so well that no direct individual rate incentives are needed. Both utilities are cooperatives and have shown their members that real cost savings are passed on to them as a result of load management. Arkansas Power & Light Co. (an investor-owned utility) has determined that a rebate to participants is appropriate for its load management program. The amount is proportional to air conditioner size ($1.44 per kilovoltampere of capacity per month) but only applies from mid-June to mid-September. Elkhorn Rural Public Power District offers reduced energy (kWh) charges to its participating customers.

All load-shifting programs that were analyzed included time-of-day (TOD) rates, which encourage participating customers to use lower-priced off-peak energy. Three of the four utilities listed in Table 2 have established firm rate schedules of this type. AEP has not yet done so but is using TOD rates on an experimental basis for the customers participating in its tests.

In addition to a complete description of the programs, experiments, and communication systems, the ADL report discusses the following.

- The concerns of utilities and regulatory agencies about load management programs: cost-benefit methodologies, consumer reaction and participation, load identification and projections, equipment capabilities and cost, and local utility characteristics
- The status of information on load management programs developed by individual utilities in response to the issues of concern cited above
- The four leading manufacturers' latest technology, products, and costs for TOD metering

The ADL final report (EURDS Report 65), which contains detailed discussions of each utility program, will be published in early 1979. *Project Manager: J. Robert Malko*

RESERVES AND RESOURCES ESTIMATION

Estimates of primary energy reserves and resources are receiving increased scrutiny. This is in response to an unprecedented growth in the number and variety of economic and policy decisions that require an assessment of fuel cost and availability over the long term. Yet the debate over energy supply continues, with estimates that range between cornucopia and imminent exhaustion. An important objective of EPRI's Supply Program is to separate fact from fancy while recognizing that certainty about future energy supplies is not achievable. Another objective is to direct research toward those questions that have the greatest payoff in improved understanding of energy resources and energy supplies.

Researchers at Massachusetts Institute of Technology (MIT) are nearing completion of a broad investigation (RP949) into the methodology and meaning of reserve and resource estimates of the primary energy fuels: oil, natural gas, coal, and uranium. A mishmash of geologic, economic, and technological concepts must be sorted through to find out what the various estimates really mean. The MIT researchers have tackled each fuel separately, analyzing the assumptions, analytic techniques, and published results of the different estimation processes. While a wealth of detailed criticism and insight has been generated by this project, the strength of the MIT research lies in its adherence to unifying economic themes. Individual estimates are being examined from the point of view of what they mean in the context of a long-run supply function (i.e., the economic relationship between costs and quantities).

Aspects of economic theory relevant to mineral resources are reviewed in the final report. At any one time, reserve and resource estimates represent a snapshot of a dynamic process of change in geologic knowledge, economics, and technology. Resources are conceptually identified and flow from category to category (e.g., from possible to probable resources and thence to proved reserves) in response to investment decisions on research, exploration, and development. Much of the confusion surrounding reserves and resources stems from an inadequate recognition of this dynamic process. The fundamental distinction between the economic analysis of mineral resources and that of other commodities is highlighted. Theoretically, at least, resources are depletable, so real long-run costs may change because of scarcity, which would be in addition to the usual production cost increase (or decrease) factors in manufacturing industries. In practice, however, the effects of scarcity have been obscure. The concept of the marginal producer as the key element in developing the long-run supply function is introduced.

Morris Adelman discusses the estimation of discovered oil and gas. Considerable attention is given to the nature of the proved-reserves record and the changes brought about in this record as a result of different types of exploration and development activities. Diminishing returns to exploration since 1950 are noted. Reserve additions due directly to new discoveries have contributed only a small portion to the total reserve additions over the last 30 years. Historically, most reserve additions have been found during coincident development and fringe exploration that follow initial discovery, but in recent years (1972–1977), slight increases in the recovery factor have dominated reserve additions. A call is made for published data on the components (both additions and subtractions) of the net reserve addition figures. No estimates of probable reserves of oil—precursor of proved reserves—are published in the United States; however, it is established that such estimates can be derived by inference.

The close links between prices, costs, and reserves are illustrated by the extraordinarily weak response of reserve additions following the 1973–1974 oil embargo. (Production rates increased during this period, but price controls strongly dampened the conversion of probable reserves to proved reserves.) However, available economic data on reserves are judged insufficient to quantitatively establish the influence of price controls as opposed to other factors, such as

escalating costs and per-barrel taxes and royalties. The increasing role of old fields for adding reserves in the United States is believed to anticipate the pattern that will develop in foreign countries. By way of elucidating different estimation processes, selected estimates of foreign reserves are also reviewed (e.g., reserves in Venezuela, Mexico, and Saudi Arabia).

Gordon Kaufman reviews the estimation of undiscovered oil and gas, giving perspective on the strengths and weaknesses of the numerous techniques that have been applied: life-cycle models, rate-of-effort models, econometric approaches, geologic-volumetric methods, discovery process models, mixed-method approaches, and the use of subjective probability in resource assessment. The object is not to identify a "best method," but rather to provide guidelines for interpreting existing estimates and for identifying appropriate methods for the circumstances.

Martin Zimmerman discusses the nature of coal data and the economic interpretation of data on coal reserves and resources. Resulting from earlier work by the author, a number of questions are raised about the adequacy of resource classification criteria, particularly seam thickness intervals, for indicating the economic recoverability of the estimated coal resource. Two points that stand out are that seam thickness alone is an incomplete guide to recovery costs and that much of the coal included in the demonstrated reserve base (estimated by the U.S. Geological Survey and the U.S. Bureau of Mines) would be available only at costs far above current costs. Better information is needed about: the distribution of coal resources, defined by seam thickness; the identity of, and distribution of coal by, economically significant nonthickness factors; the recovery factors associated with mining; and the elasticity of recovery to changes in price. Ways are shown in which insights can be obtained from existing data without resorting to the massive efforts necessary to collect new data.

Estimation of uranium reserves and resources is discussed by John Houghton. A detailed critique is given of the estimation procedures adopted by DOE's Grand Junction Office (GJO) as part of the National Uranium Resource Evaluation program. The use of "forward costing" is found to provide an inadequate economic basis for determining the long-run uranium supply function. Discounting, taxes, and long-term marginal capital costs need to be added, and the exploration component of capital costs needs to be separated. Problems in interpreting the GJO production capability analyses are pointed out, and sources of overestimation and underestimation in the potential resource evaluation procedures are outlined.

As in the treatment of undiscovered oil and gas resources, a number of different techniques that have been applied outside GJO for estimating potential uranium resources are evaluated. These include trend projection approaches, crustal abundance models, and subjective probability models. A recurring theme, here as with the other fuels, is the pitfall of failing to view reserves and resources as part of a dynamic process.
Project Manager: Jeremy Platt

New Contracts

Fossil Fuel and Advanced Systems Division

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
RP109-5	Electromagnetic Testing of Ceramic Materials	7 months	50.7	The Reluxtrol Co. *K. Kinsman*
RP422-3	Dry-Cooling Enhancement—Advanced Concept Test	18 months	685.7	Battelle, Pacific Northwest Laboratories *J. Bartz*
RP422-4	Total Evaluated Costs in Power Plant Cooling Systems	16 months	17.5	R. W. Beck and Associates *J. Bartz*
RP536-4	Evaluation of the Chiyoda Thoroughbred-121 Process at the Scholz Plant of Gulf Power Co.	15 months	524.9	Southern Company Services, Inc., and Chiyoda International Corp. *T. Morasky*
RP545-3	Deformation and Fracture of Structural Ceramics	2 years	30.0	Stanford University *K. Kinsman*
RP779-20	Conversion of Oil-Fired Boilers for Use of Coal-Derived Liquid Fuels	6 months	60.0	Stone & Webster Engineering Corp. *J. Fox*
RP779-22	Special Analytic Work	5 months	48.2	Conoco Coal Development Co. *C. Kulik*
RP979-10	Corrosion of Heat Exchanger Tubes in Fluidized-Bed Combustion	2 years	30.0	Stanford University *J. Stringer*
RP985-3	Application of Texaco Partial Oxidation Process to Power Generation	10 months	149.5	United Technologies Corp. *R. Duncan*
RP991-4	Penetration Analysis of Fossil Fuel and Advanced Power Generation Systems	6 months	12.5	Iowa-Illinois Gas and Electric Co. *O. Gildersleeve*
RP991-5	Penetration Analysis of Fossil Fuel and Advanced Power Generation Systems	6 months	29.8	Middle South Services, Inc. *O. Gildersleeve*
RP1029-1	Multistream Coal-Cleaning System—Testing, Evaluation, and Economic Assessment	3 years	800.0	Pennsylvania Electric Co. *K. Clifford*
RP1030-6	Impact of Cleaned Coal on Power Plant Performance and Reliability	5 months	45.3	Stone & Webster Engineering Corp. *J. Dimmer*
RP1031-2	Gypsum Crystallization From Wet Scrubbing Liquors	1 year	17.0	University of Arizona *R. Rhudy*
RP1041-5	Assessment of Sulfur Removal Processes for Advanced Fuel Cell System	6 months	86.9	C F Braun & Co *B. Mehta*
RP1129-2	Design and Fabrication of a Fabric Filter Test Module	2 years	476.0	Dresser Industries, Inc. *R. Carr*
RP1179-3	Development of Design Data for Commercial Atmospheric Fluidized-Bed Combustion	6 months	30.8	Combustion Engineering, Inc. *C. Aulisio*
RP1179-4	Development of Design Data for Commercial Atmospheric Fluidized-Bed Combustion	7 months	58.3	Foster Wheeler Development Corp. *C. Aulisio*
RP1180-6	Prediction of Performance of Resource Recovery Processes for Municipal Refuse	4 months	14.1	Cal Recovery Systems, Inc. *C. McGowin*
RP1180-9	Economic and Design Factors for Flue Gas Desulfurization Technology	2 months	12.5	Bechtel National, Inc. *C. McGowin*
RP1191-3	Performance Monitoring of a Passive Solar Home in Stockton, Calif.	2 years	48.6	Pacific Gas and Electric Co. *G. Purcell*
RP1193-1	Plasma Deposition of Silicon Films for Photovoltaic Devices—Phase 1	8 months	167.2	Spire Corp. *E. DeMeo*
RP1198-3	Improved Zinc Electrodes for Zinc-Halogen Load-Leveling Batteries	2 years	363.5	Case Western Reserve University *J. Birk*
RP1261-1	Treatment of Closed-Cycle Cooling Water	15 months	874.2	Stearns-Roger, Inc. *R. Jorden*
RP1261-2	Evaluation of Sulfur Dioxide and Iron Ferrate for Biofouling Control	11 months	70.7	Northwestern University *R. Jorden*
RP1262-1	Validation of Cooling-Tower Analyses	9 months	120.0	Cham of North America, Inc. *J. Maulbetsch*

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
RP1265-2	Preliminary Approach for Root Cause Analysis in Power Plants	2 months	10.0	Science Applications, Inc. *J. Parkes*
RP1266-11	Fatigue Strength of 17-4PH Stainless Steel	2 years	30.0	Stanford University *R. Richman*
RP1267-1	Slagging Gasifier Test Runs	7 months	2394.3	British Gas Corp. *N. Holt*
RP1273-1	Verification and Scale-up of Molten Carbonate Fuel Cell System	38 months	4499.5	United Technologies Corp. *E. Gillis*
RP1338-1	Instrumentation and Automation Practice in U.S. Coal Preparation Industry	7 months	52.8	Envirotech Corp. *K. Clifford*
RP1338-2	Extension of Heavy-Media Cleaning of Flue Coal	5 months	45.2	Kaiser Engineers, Inc. *K. Clifford*
RP1339-1	Evaluation of Alternative Low-NO_x Furnace Designs	1 year	256.6	KVB, Inc. *M. McElroy*
RP1341-1	Environmental Assessment of Coal Waste Disposal in Ocean Waters	5 years	600.0	New York State Energy Research & Development Authority *D. Golden*
RP1342-1	Hydraulic Transients in Circulating Cooling-Water Systems	13 months	90.0	Georgia Institute of Technology *J. Maulbetsch*
RP1345-1	Design Data for Turbine Deposition Process	14 months	512.1	Westinghouse Electric Corp. *A. Cohn*
RP1348-1	Assessments of Advanced Solar Conversion Concepts	6 months	50.3	Arthur D. Little, Inc. *E. DeMeo*
RP1349-1	Assessment of Fuel Storage and Fuel Delivery Alternatives for Dispersed Electric Utility	6 months	97.4	Bechtel National, Inc. *E. Gillis*
RP1400-1	Environmental Input for Site Selection of Coal-Cleaning Test Facility	2 months	24.5	GAI Consultants, Inc. *K. Clifford*
RP1402-2	Laboratory Absorption/ Stripping Tests	14 months	28.2	University of Texas at Austin *S. Dalton*
RP1406-2	Monitoring the Conesville FGD Scrubber Sludge Disposal Area—Phase 1	7 months	69.4	Michael Baker Jr., Inc. *D. Golden*
RP1410-1	Characterization of Full-Scale Scrubbers	3 months	128.2	Black & Veatch *R. Rhudy*
RP1412-4	Piping Modifications and Railcar Landing for Shale Oil Test Material Refinery	5 months	120.7	Paraho Development Corp. *W. Rovesti*

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
Nuclear Power Division				
RP616-2	Tornado Missile Simulation and Design Methodology	18 months	162.3	Research Triangle Institute, Inc. *B. Chu*
RP1163-1	Power Plant Performance Modeling	2 years	342.0	Bechtel National, Inc. *A. Long*
RP1166-3	Cracking of Cyclically Loaded I-600	2 years	161.2	Massachusetts Institute of Technology *T. Passell*
RP1227-2	Three-Dimensional Measurements in Two-Phase Flows	3 months	14.7	TAI Corp. *S. Kalra*
RP1236-1	Repair Welding of Heavy Section Steel Nozzles	40 months	938.8	Babcock & Wilcox Co. *K. Stahlkopf*
RP1238-2	Effects of Specimen Size and Configuration on Fracture Toughness and Ductile Instability	3 years	515.8	Westinghouse Electric Corp. *R. Jones*
RP1239-1	Effects of Trace Elements in Radiation Embrittlements	2 years	200.0	Iowa State University, Ames Laboratory *T. Marston*
RP1250-1	Uniform Waterside Corrosion of Zircaloy-Clad Fuel Rods	31 months	1368.5	Combustion Engineering, Inc. *H. Ocken*
RP1252-4	Automation of PDQ-7/ HARMONY Parameterization for LWR Assemblies	3 months	8.7	Science Applications, Inc. *W. Eich*
RP1320-1	LWR Sensitivity Analysis Using Advanced RETRAN Models	9 months	50.0	Nuclear Associates International, Inc. *J. Naser*
RP1322-1	Dynamic Turbine Generator and Condenser Models for RETRAN	10 months	148.4	Energy Incorporated *L. Agee*
RP1325-2	Preliminary Assessment of the Relationship Between Inspection Interval and Relative Leakage Probability for Larger-Diameter BWR Piping	4 months	23.5	Science Applications, Inc. *R. Jones*
RP1327-1	Basic Causes of Repetitive Failures of Nuclear and Large Fossil Feedwater Pumps	18 months	141.4	MPR Associates, Inc. *R. Swanson*
RP1328-1	Evaluation of Methods of Sealing Leaks During Plant Operation	7 months	110.2	Combustion Engineering, Inc. *T. Libs*
RP1335-1	Scoping Capability for Fuel Management Applications	15 months	58.9	Science Applications, Inc. *W. Eich*

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
RP1379-1	Development of Optical Instrumentation for LWR Safety	16 months	328.6	Lawrence Berkeley Laboratory *J. Sursock*
RP1381-1	Solution Methods for Simulation of Nuclear Power Systems	14 months	96.0	University of Arizona *E. Fuller*
RP1386-1	Development of Optimal System Configuration for Standby Emergency Diesel Generators	7 months	39.3	Systems Exploration, Inc. *B. Chu*
RP1387-1	Development and Application of Advanced Statistical Methods for On-line BWR Stability Analysis	19 months	66.0	University of Wisconsin *B. Chu*
RP1391-1	Development of a National Data System for Power Plants	9 months	70.0	Holmes & Narver, Inc. *W. Lavallee*
RP1395-2	Development of a Finite Element Model for Eddy-Current Nondestructive Test Phenomena	2 years	80.0	Colorado State University *G. Dau*
RP1395-3	Quantitative Modeling of Flow Responses in Eddy-Current Testing	2 years	102.2	Stanford University *G. Dau*
RP1396-1	Test of Job Performance Aids for Power Plants	19 months	179.4	Kinton, Inc. *R. Pack*
Electrical Systems Division				
RP1277-1	Wind Effectiveness in Transmission Line Loading	25 months	867.0	Meteorology Research, Inc. *P. Landers*
RP1288-1	Improvement in Accuracy of Prediction of Electrical Machine Constants	54 months	566.0	General Electric Co. *J. Jackson*
RP1355-2	Array and Parallel Processors in On-line Power Computations	1 year	24.9	Cornell University *D. Koenig*
RP1355-3	Security Assessment: The Alert State	1 year	39.9	Iowa State University *D. Koenig*
RP1357-1	Estimation of Life Expectancy of New and Installed Polyethylene Extruded Dielectric Cables	37 months	467.7	Phelps Dodge Cable & Wire Co. *B. Bernstein*
RP1359-1	Substation Control and Protection System	1 year	518.5	Westinghouse Electric Corp. *S. Nilsson*
RP1422-1	Analysis of Transmission Line Transients	35 months	163.7	University of Pittsburgh *S. Nilsson*
RP1427-1	Carrier Frequency Noise From HVDC Converters	3 months	30.0	General Electric Co. *N. Hingorani*
Energy Analysis and Environment Division				
RP863-1	Development of Methodology for Time-of-Day and Seasonal Load Forecasting—Part 1	15 months	89.0	The Rand Corp. *A. Lawrence*
RP949-2	Uranium Exploration Model	6 months	50.0	Massachusetts Institute of Technology *J. Platt*
RP1107-2	Electric Generating Capacity Planning Under Uncertainty—Costs and Benefits of a Technology Mix	1 year	99.9	Decision Focus, Inc. *E. Oatman*
RP1149-2	Development of a Compatible Software System for Energy Supply Modeling	1 year	35.0	Economics Analysis Associates, Inc. *A. Halter*
RP1149-3	Development of a Compatible Software System for Energy Supply Modeling	1 year	115.0	Research for Growth and Transfer, Inc. *A. Halter*
RP1224-2	Effects of Air Pollution on Lichen and Moss Microcommunities	2 years	64.9	University of Cincinnati *R. Kawaratani*
RP1293-1	Forecasts of Economic Growth and Electricity Use for Multistate Regions	30 months	775.0	Wharton EFA, Inc. *R. Crow*
RP1303-1	Utility Systems Forum	2 years	499.4	Booz, Allen & Hamilton, Inc. *D. Geraghty*
RP1307-1	Matrix Isolation Spectroscopy for Analysis of Polycyclic Organic Molecules	2 years	199.0	University of Tennessee *P. Jones*
RP1315-1	Bioassays of Air Emissions From Fossil-Fueled Power Plants	3 years	1349.9	Battelle, Columbus Laboratories *J. McCarroll*
RP1361-1	Development and Testing of Aggregate Energy Consumption Forecasting Models	17 months	194.2	National Economic Research Associates, Inc. *J. Boyd*
RP1362-1	Forecast of the Housing Stock and Its Energy-Using Characteristics	8 months	181.2	Data Resources, Inc. *J. Boyd*
RP1363-1	Analysis of Residential Response to Time-of-Day Pricing	2 years	293.9	University of Michigan *J. Boyd*
RP1433-1	Decision Framework for Technology Choice	14 months	242.8	Woodward-Clyde Consultants *R. Richels*
RP1434-1	Effects of Aerosols and Cloud Droplets on Nighttime Transformation of Sulfur Oxides	26 months	362.3	Desert Research Institute, Atmospheric Science Center *G. Hilst*
RP1435-1	Effects of Chlorine on Freshwater Fish Under Various Time and Chemical Conditions	2 years	239.1	University of Wisconsin *J. Reynolds*

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 10090, Palo Alto, California 94303; (415) 961-9043. 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 pay a small charge. Research Reports Center will send a catalog and price list on request.

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

ELECTRICAL SYSTEMS

Mutual Design Considerations for Overhead AC Transmission Lines and Gas Transmission Pipelines

EL-904 Final Report, Vol. 2 (RP742-1)

In a program jointly funded by EPRI and the Pipeline Research Committee of the American Gas Association, IIT Research Institute consolidated data and systematically investigated the effects of ac transmission lines on natural gas transmission pipelines that share rights-of-way. The resultant report can be used as a reference book that presents concise information on the prediction and mitigation of voltages and currents that were electromagnetically induced in pipelines. *EPRI Project Manager: Richard Kennon*

Longitudinal Loading Tests on a Transmission Line

EL-905 Final Report (RP1096-1)

The University of Wisconsin, Wisconsin Power and Light Co., and Engineering Research Consultants conducted full-scale tests on broken conductors and broken insulators on a 138-kV line supported by steel lattice towers. The state of the art for predicting peak dynamic longitudinal loads is reviewed and the full-scale test results are compared with predicted values from available information. The dynamic response of the supporting towers was monitored to study possible amplification of the loads introduced at the cable or insulator attachment points. The transient phenomenon following a cable or insulator rupture is discussed, and a semiempirical formula to predict impact factors is presented. *EPRI Project Manager: J. M. Silva*

Light-Triggered Thyristors for Electric Power Systems

EL-932 Final Report (RP669-1)

General Electric Co. developed a method of triggering a 53-mm, 2600-V, 1000-Á thyristor with a light source. Normally, these devices are electrically triggered, but the need for placing a large number in series for high-voltage applications made electric triggering, with its associated insulation problems, expensive and complex. In this project, a light-sensitive gating method was developed, with associated amplifying layers built integrally into the power thyristor. An LED was used as the light source. Fiber optics provided the electrical isolation and transmitted the light directly into the thyristor package. *EPRI Project Manager: Narain Hingorani*

EHV Reactor/Capacitor Switch

EL-934 Final Report (RP655-1)

Westinghouse Electric Corp. developed a high-performance device that should meet the increasing requirements of switching EHV shunt reactors and capacitors. Its successful application should provide certain improvements over existing devices, such as an enclosed design for closing contacts. One of the unique aspects of this project was the development of an interrupter capable of interrupting reactive currents at very high voltages. This permitted a drastic reduction in the required number of interrupter units, thus reducing the overall cost and improving the mechanical reliability. It was also found practical to use resistors to limit inrush currents and overvoltages. The value of the resistor supplied can be varied to suit the user's needs. *EPRI Project Manager: Vasu Tahiliani*

Installed-Cost Comparison for Self-Contained and Pipe-Type Cables

EL-935 Final Report (RP7849)

This study by Power Technologies, Inc., examined capital costs for self-contained, oil-filled cable and oil-filled pipe cable over the range of 230 kV to 765 kV for large power ratings.

Although the emphasis was on the precise comparison of the two types, care was taken to produce numbers of good absolute accuracy so that meaningful comparisons could be made with other cable types. *EPRI Project Manager: John Shimshock*

Acceptable Emergency Operating Temperatures for Extruded Dielectric Cables

EL-938 Final Report (RP933-1)

As the maximum emergency operating temperatures of extruded dielectric cables were established several years ago, they needed to be reevaluated for the materials and cable technology now available. The Institut de Recherche de l'Hydro-Québec undertook to determine satisfactory limits of operation at elevated temperatures of extruded materials and cable constructions (i.e., polymer materials used in conventional extruded cables).

The results emphasize differences and similarities in the behavior of cross-linked polyethylene and ethylene-propylene rubber materials at elevated temperatures. *EPRI Project Manager: Bruce Bernstein*

Workshop Proceedings: Power System Reliability Research Needs and Priorities

WS-77-60

The objective of this workshop was to identify the specific needs and priorities for research on power system reliability. The focus of the workshop was reliability evaluation for system planning rather than individual component design or availability analysis.

The subject of greatest interest at the workshop was the evaluation of bulk power system reliability. Various inadequacies in the modeling and data collection procedures were identified. For example, the utility industry's overriding concern in planning bulk power systems is to avoid uncontrolled, cascading outages (a dynamic problem) that result in widespread blackouts, but current models are based on steady-state conditions. The data requirements and the difficulty of computing and evaluating reliability are overwhelming when considering dynamic conditions. *Workshop Chairman: Murty Bhavaraju*

ENERGY ANALYSIS AND ENVIRONMENT

Estimation Methodology for Energy Supply From Natural Resources

EA-788 Final Report (RP871-1)

In this project, researchers at the Massachusetts Institute of Technology explored the feasibility of developing improved methodologies for the estimation of reserves and the forecasting of long-term supply of subsoil energy resources. *EPRI Project Manager: A. N. Halter*

The Effects of High-Voltage Transmission Lines on Honeybees

EA-841 Interim Report (RP934-1)

This report by Bioconcern presents results of the first year's field study of the possible effects of a 765-kV transmission line on honeybees. *EPRI Project Manager: Harry Kornberg*

Electricity Consumption in the Manufacturing Sector

EA-899 Final Report (RP208-1)

In this report General Electric Co. presents its analysis of electricity consumption in the manufacturing sector. It also forecasts electricity use for the period 1976–1990, based on alternative economic assumptions taken from three macroeconomic models. *EPRI Project Manager: Eugene Oatman*

Plume Model Validation

EA-917-SY Summary Report (WS-78-99)

An EPRI planning study determined the most appropriate development of a plume model validation protocol and an experimental program to provide reference data for model validations. This report summarizes the findings of these studies and out-

lines the recommended project structure for plume model validation. *Prepared by: Glenn Hilst*

State-of-the-Art Waste Heat Utilization for Agriculture and Aquaculture

EA-922 Final Report (TPS77-700, TPS77-734)

Tennessee Valley Authority conducted a state-of-the-art assessment of research, demonstration, and commercial projects that involve the use of power plant condenser cooling water for agricultural and aquacultural purposes. Thermal effluent uses were discussed for controlled-environment greenhouses, biological recycling of nutrients from livestock manures, soil heating and irrigation, environmental control for livestock housing, grain drying, food processing, and the culture of numerous aquatic organisms. *EPRI Project Manager: Robert Kawaratani*

Costs and Benefits of Over/Under Capacity in Electric Power System Planning

EA-927 Final Report (RP1107)

Growing demand uncertainty, coupled with lengthening lead times for new construction, is making the process of generation expansion planning more difficult for the electric utility industry. In a new approach, Decision Focus, Inc., provided a method and a working model to calculate the costs and benefits of alternative choices from the consumer's point of view. The effects of future demand uncertainty are explicitly taken into account, a step that justifies the choice of higher planning reserve margins than would otherwise be the case. *EPRI Project Manager: Eugene Oatman*

Aquatic Microcosms for Assessment of Effluent Effects

EA-936 Final Report (RP939-1)

The usefulness of laboratory freshwater lake microcosms as a tool for environmental impact assessment was studied by Lawrence Berkeley Laboratory. The microcosm system studied was a diverse assemblage of phytoplankton, zooplankton, and microbes. Three 4-month studies were carried out; each study focused on finding a different pollutant in significant concentration in the aqueous effluent from coal gasification operations. *EPRI Project Manager: Robert Kawaratani*

FOSSIL FUEL AND ADVANCED SYSTEMS

Lime/Limestone Scrubber Operation and Control

FP-627 Final Report (RP630-2)

This report by Southern California Edison Co. describes the major components of lime/limestone scrubbers and utility industry experience obtained with scrubber control systems.

Control problems can be aggravated by scale formation inside scrubbing equipment, especially on control sensors. Although lime and limestone scrubber chemistry is still not completely understood, much engineering know-how was developed. This know-how was used to resolve most of the control problems observed in full-scale scrubbing systems and is now being used in designing scrubbing systems for subsequent startup in the early 1980s. *EPRI Project Manager: Thomas Morasky*

Analysis of Variations in Costs of FGD Systems

FP-909 Final Report (RP209-2)

In an analysis of variations in the cost of flue gas desulfurization systems, Battelle, Columbus Laboratories examined the factors affecting cost estimates, actual costs, and competitive bids. *EPRI Project Manager: Thomas Morasky*

Flue Gas Conditioning for Enhanced Precipitation of Difficult Ashes

FP-910 Final Report (RP724-1)

A review of prior investigations indicated that the effectiveness of ammonia and triethylamine as conditioning agents used to improve the performance of electrostatic precipitators was inconclusive. When successful conditioning occurred, it was sometimes impossible to determine the process by which the conditioning agent affected performance. In this project Southern Research Institute examined the effectiveness of these two conditioning agents with respect to the attenuation of resistivity and the suppression of back corona. *EPRI Project Manager: Walter Piulle*

Application Survey and Evaluation of Gas Turbine Needs

AF-911 Final Report (RP990-1)

Factual data are essential to guide EPRI's formulation of gas turbine research. Thus, an extensive survey was made of 38 representative utilities to determine their needs for gas turbine unit additions and to determine potentially beneficial research for resolving problems with gas turbine units. The overall results of this survey by Ebasco Services, Inc., are presented with supporting statistics and commentary. *EPRI Project Manager: Richard Duncan*

Effects of Sulfur Emission Controls on the Cost of Gasification–Combined-Cycle Power Systems

AF-916 Final Report (RP239)

Fluor Engineers and Constructors, Inc., performed economic evaluations for a series of coal gasification–combined-cycle power generation facilities, each different in the mode of operation of the sulfur-removal unit. The objectives of the study were to determine the added cost of power associated with more stringent sulfur emission requirements, as well as the economic impact of the pressure level at which the sulfur removal unit was operated. *EPRI Project Manager: Michael Gluckman*

1975 Wilsonville Operations on Illinois No. 6, Pittsburgh No. 8, and Wyoming Coals

AF-918 Interim Report, Vols. 1 and 2 (RP1234)

This report by Catalytic, Inc., covers the operation during 1975 of the 6-t/d solvent-refined coal (SRC) pilot plant at Wilsonville, Alabama. Three high-sulfur bituminous coals and one low-sulfur subbituminous coal were processed over a significant range of independent reactor parameters. The subcontractor was Southern Company Services, Inc. *EPRI Project Manager: Norman Stewart*

Control of NO_x Emission by Stack Gas Treatment

FP-925 Final Report (RP783-1)

Battelle, Columbus Laboratories conducted a state-of-the-art review of stack gas treatment methods for the control of NO_x emissions. More than 45 individual processes for removing NO_x from stack gas were identified.

Most of the active process development is taking place in Japan. The patent protection issued in the United States to Japanese companies may dominate this technology in the future. The three leading stack gas treatment techniques for NO_x control are catalytic reduction with ammonia, noncatalytic reduction with ammonia, and direct scrubbing of NO with simultaneous absorption of SO_2. The wet processes are much less developed than the dry processes.

The transfer of Japanese technology on NO_x control to the United States should be viewed carefully. The technology is still in a relatively early stage of development and a cost-benefit analysis has yet to be performed. Pilot plant testing should be carried out to investigate the application-related problems for U.S. coals. *EPRI Project Manager: Navin Shah*

Economic Study of the ToscoDyne Gasification–Combined-Cycle System for Electric Power Generation

AF-930 Final Report (RP239)

Fluor Engineers and Constructors, Inc., performed an economic screening study for producing electricity from coal in the ToscoDyne process developed by Tosco Corp. and Hydrocarbon Research, Inc. In this process, coal is initially pyrolyzed in a retort developed by Tosco and converted into intermediate-Btu gas, liquid product, and char. The char is then converted into low-Btu gas in an air-blown fluidized-bed gasifier developed by Hydrocarbon Research, Inc. In this project the process was integrated with a combined-cycle power plant, based on advanced gas turbine technology estimated by Westinghouse to be available in the 1981–1985 time period. The evaluation was based on a complete grass-roots facility sized to conform to the present electric utility practice of building units of approximately 1000-MW capacity. *EPRI Project Manager: Michael Gluckman*

Proceedings of the Second Geothermal Conference and Workshop

WS-78-97

Prepared by Altas Corp., these proceedings are a compilation of papers presented at the Second Geothermal Conference and Workshop. The papers report the results of EPRI-sponsored geothermal research projects and R&D sponsored by electric utilities and resource companies. The papers also present the views of various representatives of industry, government, the public, and financial institutions on risks associated with geothermal development and how these risks might be shared. *EPRI Project Manager: Vasel Roberts*

NUCLEAR POWER

The HAMMER Code System

NP-565 Key Phase Report (RP709)

The analysis of thermal reactor benchmark experiments is one of the principal means that can be employed to test the adequacy of basic nuclear data sets for reactor calculations. If the analysis is sufficiently sophisticated and is applied to integral measurements for which experimental data of good accuracy are available, discrepancies between calculations and measured values may be attributed to the quality of the basic data.

One of the thermal reactor analysis codes that has been frequently used for lattice studies is the HAMMER program. This report, by Technion-Israel Institute of Technology, describes the current version of the HAMMER code in detail and the nuclear data library processing codes needed. Particulars of other improvements made in the code are also included, as well as the manner in which the code prepares few-group lattice parameters for subsequent calculations relating to an entire reactor core. *EPRI Project Manager: Odelli Ozer*

An Evaluation of Eddy-Current Inspection Methods for PWR Steam Generator Tubing

NP-636 Final Report (TPS77-709)

Eddy-current testing is the inspection method most commonly used to satisfy regulatory requirements for the in-service inspection of nuclear steam generator tubing. In the past this test has been successful in detecting such problems as wastage and corrosion in straight sections of the steam generator tubing. However, the tube deformation known as denting (in the tube support area) provides the inspector with complex eddy-current signals that may mask flaw indications. The performance and applicability of improved technology are variable, and there are practical incentives to obtain more precise measures of performance. To study the performance of new systems, as well as to define a baseline for existing steam generator inspection capability, EPRI initiated the round-robin evaluation described in this report by Battelle, Columbus Laboratories. Four systems were evaluated by a panel of in-service inspection specialists and NDE consultants. *EPRI Project Manager: Gary Dau*

Surface Effects in the Transport of Airborne Radioiodine at Light Water Nuclear Power Plants

NP-876 Final Report (RP274-1)

Past experience has indicated that radioiodine in ventilation effluents from light water reactors aged from the point of emanation within the plant to the point of plant effluent release. As used in the context of this report, aging implies that there was a greater reduction in the concentrations of the isotopes with shorter half-lives compared with what would be expected from normal ventilation airflow rates and that there was a change in the chemical form from the more reactive elemental form to the less reactive organic form. This study was conducted by Science Applications, Inc., to determine if the interaction of airborne radioiodine with surfaces could have been the cause. *EPRI Project Manager: Henry Till*

BEHAVE-4: LWR Fuel Rod Analysis Code

NP-892 Topical Report (RP397-3)

This report by Science Applications, Inc., describes the BEHAVE-4 code for LWR fuel rod analysis and provides instructions for its use. The code employs the finite element method with cylindrical symmetry and generalized plane strain to predict fuel and cladding temperatures, stresses, and deformations during normal power operations. The method of solution is generally similar to that in BEHAVE-2, a fast reactor code, because BEHAVE-2 was modified to form a basis for BEHAVE-4. *EPRI Project Manager: Floyd Gelhaus*

Three-Dimensional Pool Swell Modeling of a Mark I Suppression System

NP-906 Final Report (RP693-1)

SRI International conducted a study of the dynamic response of a Mark I pressure-suppression system during the early air-discharging phase of a postulated loss-of-coolant accident (LOCA). Tests using a 11.7-scale model yielded quantitative information on the vent-clearing process, the pool swell, the loads on the torus and the ringheader, and many other dynamic responses of interest. Corresponding information for the reference plant from which the model is scaled can be obtained from the test results and the scaling laws given in the report. *EPRI Project Manager: Charles Sullivan*

Analysis and Testing of Steam Chugging in Pressure Systems

NP-908 Interim Report (RP1067-2)

Chugging is a semiperiodic phenomenon produced by injection of steam into a pool of subcooled water and its subsequent condensation. During a hypothetical LOCA, chugging could induce significant loads on some BWR containments. It has therefore received increased attention from both the nuclear industry and the NRC.

SRI International performed experimental studies of steam condensation on injection downward into a pool of subcooled liquid. This report presents pool pressure data in statistical form; although the data vary widely, some trends are identified. *EPRI Project Manager: Jean-Pierre Sursock*

Location of Condenser Leaks at Steam Power Plants

NP-912 Final Report (TPS78-775)

Science Applications, Inc., demonstrated the feasibility of using helium to locate water leaks in power plant condensers. This report presents details of the equipment and procedures used. It is shown that the helium method can detect leaks approximately 1/100 the size of leaks detectable by methods currently used. The helium method can also be used to estimate the position of a leak along the condenser tube. *EPRI Project Manager: Roy Swanson*

Feasibility of Determining Stress in BWR Pipes With the DRI X-Ray Stress Analyzer

NP-914 Interim Report (RP823-1)

The Denver Research Institute (DRI) undertook a project to investigate the feasibility of fabricating an X-ray stress analyzer for measuring residual stress in austenitic stainless steel pipe. The resulting data indicated that it would be feasible to design an instrument based on the DRI technology and apparatus. It was recommended that the proposed instrument be designed, fabricated, and delivered in the next phase of the project. *EPRI Project Manager: Gary Dau*

Critique of the PLBR Phase-A Guidelines

NP-915 Final Report (RP620-25)

Argonne National Laboratory performed a critical analysis of the core-blanket complex (as defined in the Phase-A LMFBR Pool Guidelines) with respect to the consistency and feasibility of nuclear, thermal, and mechanical design assumptions. Recommendations were made for changes in fuel assembly design, core configuration, and orificing. *EPRI Project Manager: Edward Fuller*

Evaluation of In Situ Testing Methods for High-Amplitude, Dynamic Property Determination

NP-920 Final Report (RP769-2)

This report by Fugro, Inc., presents a review of procedures that can be used for in situ determination of dynamic soil properties at earthquake-compatible strain amplitudes as required for soil-structure interaction studies. The purpose of this review was to document test procedures and concepts and to present the advantages and limitations associated with these methods from both theoretical and practical standpoints. The study involved a review of published literature relevant to the topic and discussions with various individuals from academic, consulting, defense, and government organizations with expertise in the fields of wave propagation, in situ testing, and solid mechanics. *EPRI Project Manager: Conway Chan*

Acoustic Emission Monitoring and Ultrasonic Examination Correlation on a Reactor Pressure Vessel

NP-921 Final Report (RP448)

Acoustic Emission Technology Corp. and General Electric Co. undertook the acoustic emission (AE) monitoring and the corroborative ultrasonic examination of the AE locations established during the hydrostatic pressure test of a full-scale BWR primary pressure vessel. Descriptive information on AE is provided as a background and details of the AE and ultrasonic instrumentation, procedures, problems encountered, and test results are discussed. In total, 42 acoustic emissions were detected and located and ultrasonically examined during this project. *EPRI Project Manager: Karl Stahlkopf*

Steam Turbine Rotor Reliability

NP-923 Interim Reports and Summary Report (RP502)

An automated steam turbine rotor analysis project (STRAP) has been developed to facilitate the prediction of rotor lifetime, given the duty cycle of the turbine and the results of ultrasonic examination from the rotor bore. The contractors in this project

are Battelle, Columbus Laboratories, Southwest Research Institute, and Westinghouse Electric Corp. *EPRI Project Manager: Floyd Gelhaus*

Comparisons of RETRAN and Two-Velocity, Two-Phase Flow Models With Experimental Data

NP-928 Interim Report (RP958-1)

Energy Incorporated conducted a study of several aspects of two-phase flow models and computer programs associated with steady-state and transient analyses of nuclear steam supply systems.

The results of the investigations showed the accuracy and ease of application of RETRAN, some of the limitations associated with homogeneous equilibrium mixture models of two-phase flow, and some of the areas in which RETRAN can be improved. *EPRI Project Manager: Lance Agee*

Analyzing the Reprocessing Decision: Plutonium Recycle and Nuclear Proliferation

NP-931 Final Report (RP620-24)

The United States decision to defer indefinitely the reprocessing of spent nuclear fuel is examined in this report by Stanford University. Bayesian decision analysis is applied to develop a rational framework for the assessment of alternatives. Benefits and costs for each alternative are evaluated and compared in dollar terms to determine the optimal decision. A fuel cycle simulation model is constructed to assess the economic value of reprocessing LWR spent fuel and recycling plutonium. In addition, a dynamic fuel substitution model is used to estimate the economic effects of the reprocessing decision's influence on the introduction date of the LMFBR. The analysis of benefits and costs is extended to include the social costs from technological risks, such as accident risk, nuclear theft and/or sabotage, and international nuclear proliferation. These social costs are expressed in dollar terms for comparison with conventional economic values. *EPRI Project Manager: Robert Williams*

Sources of Radioiodine at PWR Plants

NP-939 Final Report (RP274-1)

This report by Science Applications, Inc., determines specific components and operations at operating PWR plants that have a potential for being significant emission sources of radioactive iodine. The relative magnitudes of these specific sources in terms of the chemical forms of the radioiodine and the resultant annual averages from major components are established. The data are generalized for industry predictive purposes. *EPRI Project Manager: Henry Till*

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Material is listed by subject category; comprehensive articles are indicated by page numbers printed in bold type. Special groupings include: *EPRI, Features and editorials, Government activities, Meetings,* and *People.* The abbreviations used for the combined issues are JF (January/February) and JA (July/August).
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