Coping With Zero Discharge

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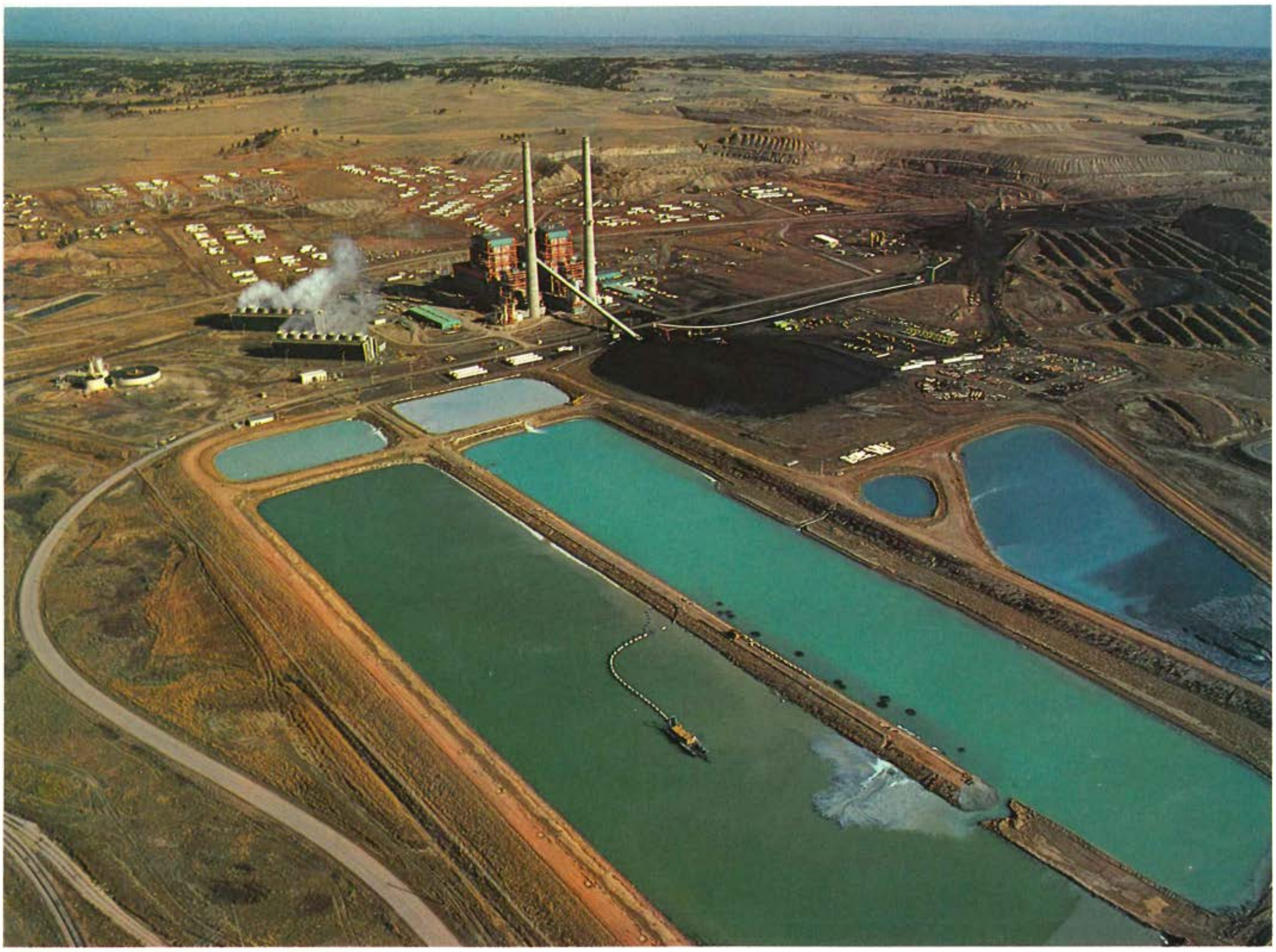

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Cover: Evaporation ponds at Montana Power Co.'s Colstrip zero discharge plant. To avoid costly construction of additional ponds, utilities must be especially careful in managing water.

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Zero Discharge: New Approaches to Water System Design

In the last 10 years the term *zero discharge* has entered the lexicon of utility water management and environmental affairs. This simply means that no wastewater streams are discharged from a power plant to surface receiving waters. The only water to leave the plant does so in the form of moisture either evaporated to the atmosphere or contained in ash and sludge waste products. This approach to water system design in coal-fired power plants results from the convergence of two forces—water shortage at the inlet and regulations at the outlet.

At the inlet, water shortages and the emergence of water supply as a major siting constraint have led to increased attention to the recycle and reuse of water within the plant. Cooling towers, scrubbers, ash ponds—every water-using plant system—are operated at higher and higher cycles of concentration. Slightly dirty water is diverted to areas that can accept a lower quality. As a result, after the water has been progressively recycled, it contains a higher level of suspended and dissolved contaminants than was the case in past designs.

At the outlet, various regulations have been imposed. In the Colorado River Basin, for example, where increased salinity has long been identified as a problem to downstream users, water may not be returned to the river at a lower quality than withdrawn. Clearly, if the discharge water has been upgraded to source water quality, there is no reason to discharge it.

As long as water is retained within the plant, federal discharge regulations do not apply. Nevertheless, zero discharge imposes a strict discipline on plant designers, builders, and operators to monitor and control the recirculating water within the plant to ensure efficient water use. Even small deviations from plant design or operating procedures, which would seem negligible in effect, can bring about a major effect on the evaporation pond inventory. For example, 10 gallons a minute, the approximate flow from a hand-held garden hose, may not seem significant in comparison with the volume of water used within a 500-MW (e) power plant, but it can disrupt the water balance. An extra 10 gallons a minute requires 10 acres of evaporation pond at a cost of $100,000 an acre. One garden hose, therefore, becomes a million-dollar problem. This has been substantiated at many plants where multi-million-dollar modifications of water management systems and evaporation ponds have been required.

Everyone associated with power plant water system design and operation must become acutely aware of this water management problem. This month's cover story is intended to be part of this consciousness-raising. Several efforts to develop the tools for tighter water management are under way or planned: A zero discharge symposium, at which information and experience on these systems will be exchanged, is scheduled for later this year. Eventually, a series of design and operating manuals will be prepared to assist in making zero discharge a more reliable, cost-effective approach to an increasingly important and difficult aspect of power generation.

John S. Maulbetsch
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Authors and Articles

Water for power plants is getting scarce. Growth and development, especially in the West, mean economic competition for water, just as for land and fuel. Moreover, waste water is getting more difficult to handle. Avoiding contamination of aquifers and waterways means expensive and rigorous treatment of effluents.

Balancing the Water Budget (page 6) explains the virtually closed-cycle water systems devised by utilities to deal with both problems. Nadine Lihach, *Journal* feature writer, also enumerates many of the problems that arise and have now become topics of EPRI-sponsored R&D as zero discharge gets serious scrutiny for widespread application in power plant design.

Three staff members of EPRI's Water Quality Control and Heat Rejection Program aided Lihach in developing the article: Winston Chow, Roger Jorden, and John Maulbetsch. Winston Chow, a specialist in water quality, came to EPRI in February 1979 after more than six years with Bechtel Power Corp. His experience there included the design of water and wastewater management systems for both coal-fired and nuclear power plants. Chow is a 1968 chemical engineering graduate of the University of California at Berkeley. He earned his MS at San Jose State University in 1972.

Roger Jorden, an EPRI project manager since March 1976, has been on loan to the Colorado-Ute Electric Association, Inc., for two years and is responsible for coordinating zero-discharge efforts at two power plants. Jorden was previously a water pollution control consultant, and he was on the engineering faculty at the University of Colorado for six years. He graduated in geology from the University of Texas, then earned an MS in hydrology at the University of Arizona and a PhD in sanitary engineering at the University of Illinois.

Maulbetsch, program manager since August 1975, was previously director of the energy technology center at Dynatech R/D Co. Earlier in his eight-year association with Dynatech he directed a two-year study for EPA on the technical and economic aspects of thermal pollution abatement in power plants. Maulbetsch holds BS, MS, and PhD degrees in mechanical engineering from MIT, where he was an assistant professor for three years.

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Knowledge of what utilities are doing in their own R&D studies is an obvious component of EPRI's program planning. In the case of solar energy technologies, the number, distribution, and value of work change so fast that annual surveys have been necessary to stay current. **Solar Update** (page 12) reviews the major shifts detected in EPRI's 1980 survey data, notes some of the probable reasons, and describes the status of some major solar R&D programs that involve utilities.

The article was written by Margaret Laliberte, science writer, with guidance from Edgar DeMeo, manager of the Solar Power Systems Program in EPRI's Advanced Power Systems Division. A staff member since August 1976, DeMeo initially specialized in photovoltaic and wind energy conversion research. Before joining the Institute, he was on the engineering faculty at Brown University for seven years, and he taught at the U.S. Naval Academy for two years. DeMeo is an electrical engineering graduate of Rensselaer Polytechnic Institute and earned MS and PhD degrees at Brown.

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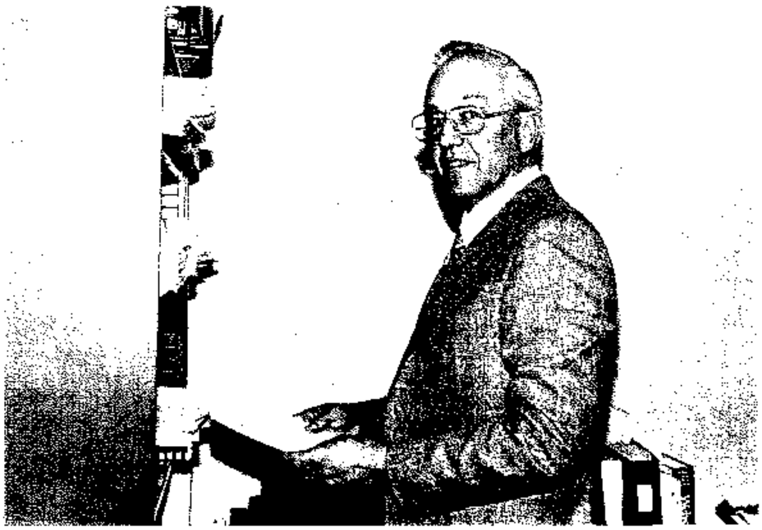
Energy conservation is increasingly seen as a matter of wise use rather than nonuse. In a changing world, the inflexibility of the earlier interpretation was enough to make it obsolete. But identifying the newer definition doesn't alone bring about its universal application. If one word is most important in encouraging wiser use of energy, it must be *strategy*. The strategy for energy conservation is changing in the United States today, so it's appropriate to review the energy-using sectors and the technologies that offer conservation opportunities to electric utilities.

Shifting Emphasis in Conservation Strategy (page 16) focuses on the R&D avenues laid out by EPRI's Energy Utilization and Conservation Technology Department. Science writer John Douglas worked closely with the department director, Orin Zimmerman, in describing the principal techniques and equipment being investigated.

Zimmerman brings a long background of utility experience to his guidance of this EPRI research. For 32 years with Portland General Electric Co., he worked in operations, distribution engineering, and marketing, then came to EPRI in February 1979 after serving four years as PGE's general manager of conservation and energy management. There he was responsible for company contributions in research, electric codes, operating procedures, and customer service practices to advance energy conservation.

DeMeo



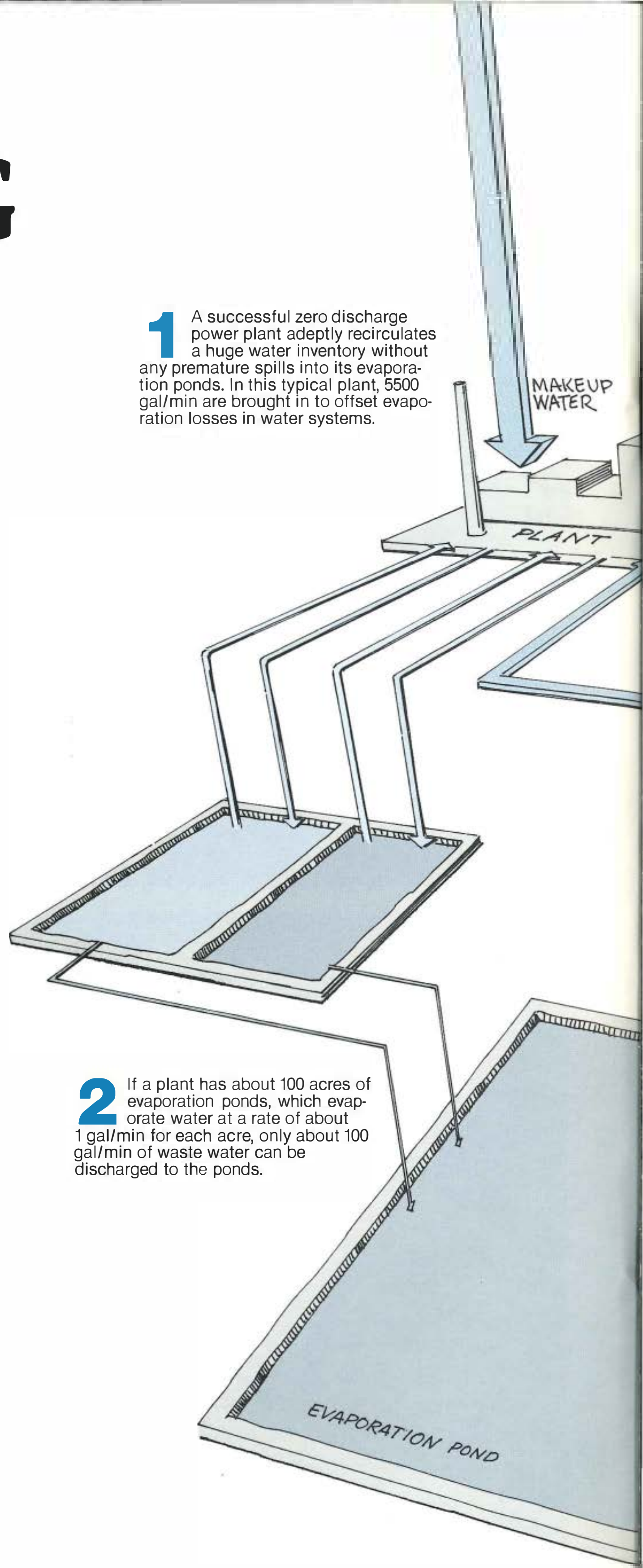
Zimmerman

Chow Maulbetsch

Jorden

BALANCING THE WATER BUDGET

The number of zero discharge power plants that recycle their vast water inventories is increasing in response to tighter environmental regulations. Some 30 such plants are already in operation, mostly in the West. As long as water is retained within these plants, federal discharge regulations do not apply, but owners are realizing that scrupulous design, operation, and maintenance of water systems are necessary to avoid costly mistakes.

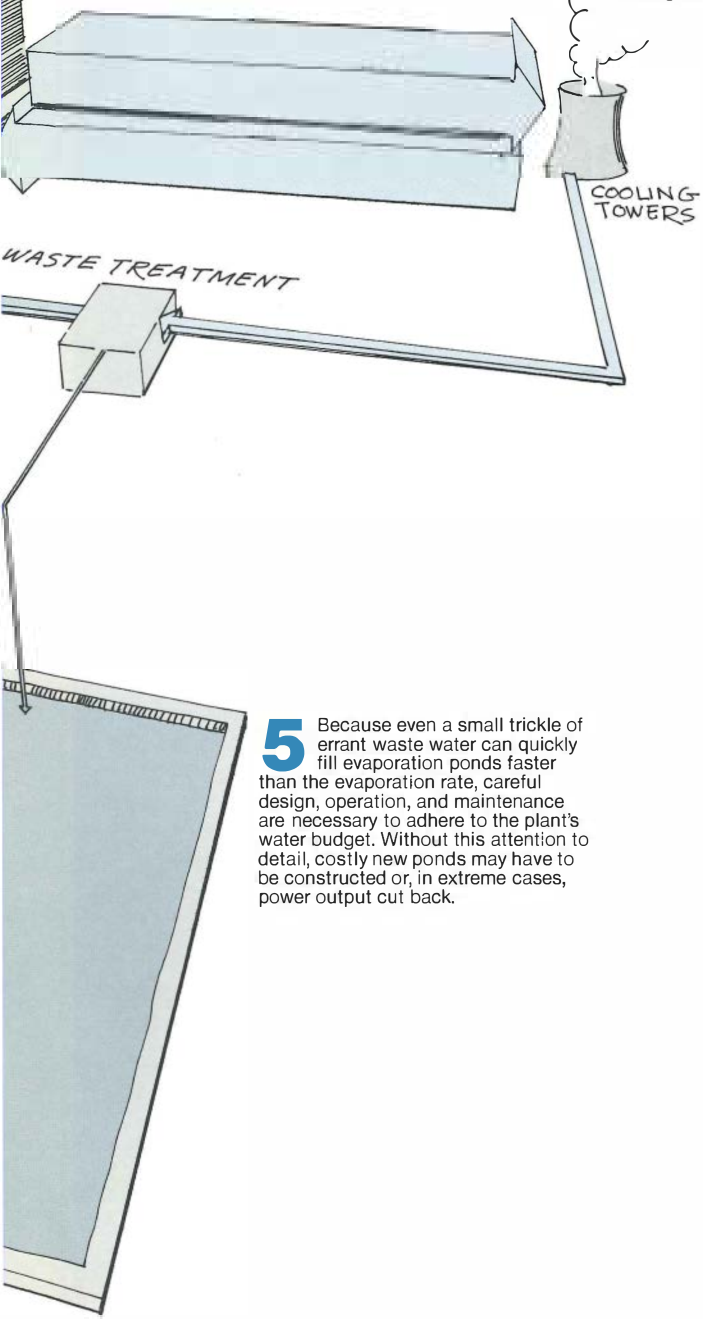


1 A successful zero discharge power plant adeptly recirculates a huge water inventory without any premature spills into its evaporation ponds. In this typical plant, 5500 gal/min are brought in to offset evaporation losses in water systems.

2 If a plant has about 100 acres of evaporation ponds, which evaporate water at a rate of about 1 gal/min for each acre, only about 100 gal/min of waste water can be discharged to the ponds.

3 The rest of a plant's water inventory—hundreds of thousands of gallons per minute—must be recycled within the plant. Along the way, water may be treated to upgrade it for reuse.

4 The highest-quality water goes to the most sensitive plant systems, such as the boilers; intermediate-quality water goes to less sensitive systems, such as cooling towers and flue gas desulfurization equipment. The lowest-quality water is consigned to the evaporation ponds.



5 Because even a small trickle of errant waste water can quickly fill evaporation ponds faster than the evaporation rate, careful design, operation, and maintenance are necessary to adhere to the plant's water budget. Without this attention to detail, costly new ponds may have to be constructed or, in extreme cases, power output cut back.

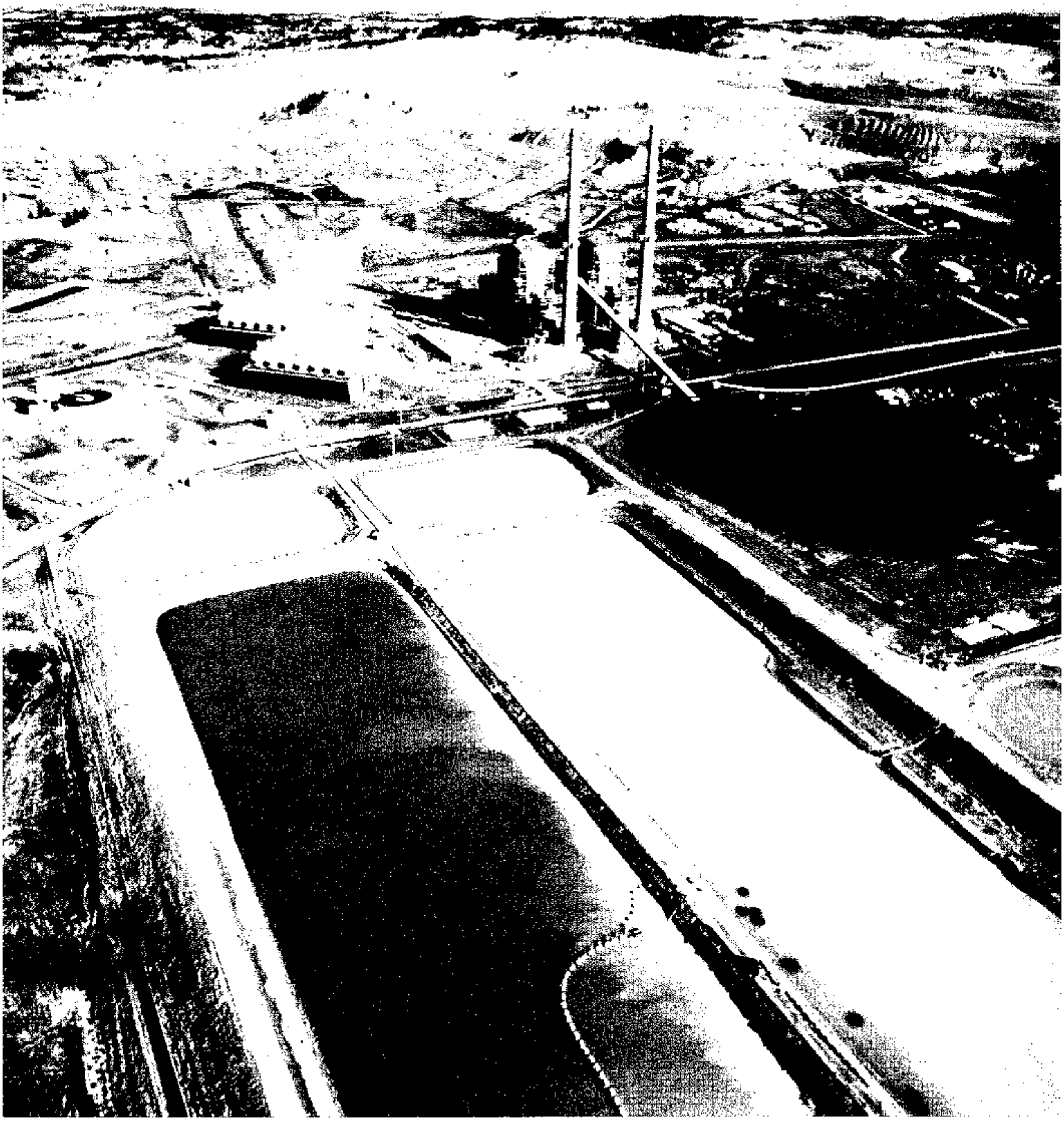
Power plants not only consume fuel; they also thirst for water. Thousands of gallons a minute are required daily for essential jobs within a plant. Water condenses the steam that drives the turbines, feeds the boilers, cools the plant, sluices the ash, scrubs the flue gases, and supplies the plant's drinking fountains. Part of this water is consumed; part of it is discharged after its job is completed.

Once the water is discharged, however, it is subject to water quality regulations. Depending on the original quality of the water and its use inside the plant, it may contain or collect traces of substances considered pollutants by EPA: arsenic or cadmium from coal, for example, or chlorine added to inhibit the growth of algae and slime in cooling waters. The environmental guidelines and standards that require removal of these pollutants are getting stricter; consequently, the cost of removing the pollutants from the discharge water is getting higher. Systems based on zero aqueous discharge are one solution to the problem.

Use and reuse

Zero discharge plants, as the name implies, discharge no water to the environment. Whatever water is taken in by the plant is typically used over and over again. As Winston Chow, manager of EPRI's water quality control subprogram, describes this recycling, the highest-quality water is used in the most sensitive plant systems, such as the boilers. Lower-quality water is used for cooling towers. As the quality of the water is degraded by use, it is relegated to such systems as ash-handling, where water quality is less critical. When necessary, the water is treated to reduce scaling, corrosion, and biofouling in plant equipment. Makeup water is added to replace water inevitably lost by evaporation within plant systems.

At Montana Power Co.'s 700-MW Colstrip zero discharge station, water retention ponds occupy about 180 acres. Pond contents vary: approximately 110 acres are devoted to wastewater evaporation; some 20 acres are for cooling-tower blowdown; 25.7 acres are for fly ash from the plant's scrubbing system. Because ponds cost an average of $100,000 per acre to construct, utilities must keep pond acreage—and therefore wastewater discharge—to a minimum.



Eventually, all that remains of the original water is a concentrated brine slurry, which is fastidiously disposed of in onsite evaporation ponds.

More than 30 zero discharge plants are now in operation in the United States; most are coal-fired plants, but some are nuclear, oil, or gas plants. Almost all were built in the last 10 years, and most are located in the arid West. In some cases the utilities that built these plants incorporated zero discharge systems because state or local water quality regulations required them. In other cases the regulations were so stringent that the quality of the water treated for discharge was equal to or better than the quality of the plant's original water supply, and so it was uneconomical to discharge the water once it had been treated. Although zero discharge plants are unaffected by the water quality regulations that bind conventional plants, they too have their challenges.

Zero discharge plants must adeptly juggle thousands of gallons of recirculating water without spilling any. All water recycling and disposal is governed by a water budget, which is strictly decreed by the total available wastewater evaporation capacity of the plant, including ponds and subsystems, such as cooling towers. In the hot, arid West, it takes a full acre of pond surface one minute to evaporate about one gallon of waste water.

If too much water reaches a plant's evaporation ponds, the plant's evaporation capacity could easily be exceeded. When one plant was being started up, for example, a cooling-tower basin overflowed into an evaporation pond at a rate of 11,000 gal/min (0.69 m^3/s) for just 19 hours, depleting two-thirds of the total year's budgeted flow in a single day. Because a zero discharge plant cannot release any waste water, the penalty for an overflow can be severe—more ponds must be built or existing systems must be redesigned to reconcile the water budget.

Roger Jorden, EPRI project manager now stationed at a zero discharge plant, stresses that the construction of new ponds and the redesign of older systems are both costly alternatives. Lined ponds can cost up to $100,000 an acre to construct; if an acre of pond takes about a minute to evaporate a gallon of waste water, an extra 10 gal/min (2.3 m^3/h)—the output of a garden hose—could conceivably cost $1 million in additional pond construction. System redesign and retrofit costs vary widely from situation to situation, but are also high. Nevertheless, if these remedies are not taken, power production may have to be curtailed to cut back on water output, and replacement power, at $150–$750 a day per megawatt, will have to be purchased.

Despite the penalties, zero discharge systems have only recently begun to get the meticulous attention they deserve. The delayed effect of faulty zero discharge system design and operation is partly to blame. Because it can take months or years for the evaporation ponds of a new plant to approach capacity, a poor design or inadequate operation procedures may not be immediately apparent. Utility attitudes toward water management have also had an effect. Until recent environmental controls were enacted, utilities had little reason to attach high priority to water management within power plants. Zero discharge has begun to change that, but utilities and power plant architect-engineers are still more concerned with plant boilers and turbines than with fugitive leaks and water runoff.

Correct design

Accurate design is the starting point for achieving optimal zero discharge systems. "Retrofitting is always more expensive than designing a plant right the first time," emphasizes John Maulbetsch, EPRI manager for the Water Quality Control and Heat Rejection Program. The labyrinth of pipes, drains, and basins is already in place; revisions in existing systems may be obstructed by the close crowding of other plant systems. Sometimes systems are buried beneath the plant and can only be reached through excavation. Plant blueprints may not be entirely up-to-date, further thwarting retrofits.

Because of these engineering complications, there are formidable budget problems involved with going back and redesigning a zero discharge system. And the cost of new systems and construction is not the only consideration; a utility may also have to purchase replacement power while the problem plant is out of commission. Plainly, a plant must be designed correctly from the start to avoid costly problems later.

Supplying a plant with the best zero discharge system possible is no simple matter, however. Even seemingly small design considerations can make significant differences in the closed zero discharge system, and utilities and architect-engineers alike must be fully aware of these differences. But as these systems are relative newcomers to the power industry, the methods and data needed to design them are not well established. Further, architect-engineering firms do not usually exchange design information. They also receive little utility feedback on a given design because serious problems may not materialize for months or years after a plant has been completed and turned over to its utility owners.

At EPRI, the Coal Combustion Systems Division's water quality control research is attempting to close this critical information gap. One effort is an ongoing study of water management in coal-fired power plants, including zero discharge systems. To begin to find out how individual utilities manage plant water, EPRI contractors Stearns-Roger, Inc., and Water Purification Associates surveyed several plants and summarized the design and operating practices they encountered. The limited data available on the amount and quality of water required for each plant subsystem were collected; the drop in water quality through use in each subsystem had to be estimated because of lack of actual data.

With information from this and similar studies, utilities and architect-engineers can begin to review how plants deal with water management and zero discharge. A later phase of the study will outline a systematic approach to water management in the design and operation of coal-fired power plants. (Definitive data on water consumption and chemistry will also be established.) Future efforts will validate these design methods by trying them out in a new plant design or in retrofitting an existing plant.

Another way of promoting cross-fertilization of design ideas and experiences is to conduct symposiums. An upcoming EPRI zero discharge symposium, scheduled for September 21–24 in Colorado, will give utilities and architect-engineers their first real chance to meet and exchange notes on zero discharge system design, management, operation, and maintenance. A special aim of the symposium is to compile a set of zero discharge design guidelines that utilities and architect-engineers can follow when they construct new plants. These guidelines will be incorporated into a design manual that EPRI will publish next year.

Careful operation

Correct design is only the start of a good zero discharge system. The best system designs can be worthless if they are not properly operated and maintained. Because the zero discharge system is so unforgiving of mistakes, operators must always keep a close eye on the collection, segregation, reuse, treatment, and disposal of the plant's vast water inventory. Inadvertent discharges of plant water are of particular concern because they may endanger the plant's water budget. Such discharges can result from anything from a leak in a major system to an overliberal use of service water for washing plant equipment.

Operators must be both well trained and properly motivated if these unplanned discharges are to be avoided. Yet often, the least-experienced operators are assigned to water systems. As soon as they become proficient, they are promoted up and out to other plant areas. Water management and water quality positions must therefore be upgraded to keep experienced operators on the job. Appropriate training courses and manuals are also necessary to instruct the operators in their jobs, and operators must be made aware of the importance of their jobs to plant operation.

Beyond training, operators also need suitable equipment to keep zero discharge systems running smoothly. Flow meters and other instrumentation that indicate the quality and quantity of a given stream are essential for tracking down the source of an errant wastewater flow, or determining the quality of a water stream for proper segregation. Such monitoring devices are often inadequate, improperly maintained, or lacking at older zero discharge plants, and those at many newer plants have improved but still limited capability. In addition to better monitoring and instrumentation, operators can also benefit from such simple aids as color-coded drains to ensure that service water of one quality is not combined with water of a different quality.

Another operating concern at zero discharge plants is water treatment. This is of special consequence because the evaporation of water through repeated cycles of use concentrates any impurities present in water. Uncorrected, this concentration of impurities can lead to scaling, corrosion, and biofouling, all maintenance headaches.

Scaling is caused when dissolved salts, such as calcium carbonate, calcium sulfate, and silica, reach the point of saturation and precipitate out of solution. These precipitates form insulating scale deposits on the plant's condensers and other heat exchangers. Scaling degrades overall plant performance; in extreme cases the plant may have to be shut down so the condensers can be cleaned with water lances and circulating acid solutions. Corrosion comes about when the oxygen and carbon dioxide dissolved in water attack susceptible metals in plant equipment, and the weakened parts must eventually be replaced. Biofouling results when microorganisms present in water colonize power plant systems and impede heat transfer. This biological growth must be removed to keep the plant at optimal performance.

In conventional plants, scaling, corrosion, and biofouling are usually controlled by chemical treatment and by blowdowns, where water is flushed from the plant, sometimes treated, and then discharged. But zero discharge plants, keeping within a straitjacket water budget, cannot afford the luxury of frequent blowdowns and so must rely on chemical treatment or evaporation to keep recirculating water at a reasonable level of quality.

In cooling towers, for example, the addition of zinc, chromium, and phosphorus compounds can mitigate scaling and corrosion; chlorine additives can control biofouling. Water can also be treated through mechanical evaporation. For instance, cooling-tower blowdown can be channeled through a vapor recompression–evaporation system. The distillate is returned to circulation, and the impurities are sent on to the plant's ponds as concentrated salt solutions or slurries.

Costly conservatism

Water treatment and evaporation quickly become expensive when applied to the large quantities of water recirculating within a zero discharge plant. Utilities prefer to use water for as long as possible and to resort to treatment or evaporation as little as possible. Unfortunately, given the current state of the art, power plant operators don't know exactly when the impurities in recirculating water are approaching saturation. If the saturation limits are exceeded, troublesome solids precipitate and can cause shutdown of the entire plant for maintenance. Because the data on saturation levels in power plants are so limited, operators prudently run plants well below what are believed to be the saturation thresholds. This conservative approach means water must be treated or disposed of before its time, which in turn requires more makeup water, more water treatment or ponding, and more money.

Chow provides a staggering example of the dollar penalties. Assume a 500-MW plant that operates at 5 or 6 cycles of concentration (that is, the water is recirculated 5 or 6 times). The blowdown from such a plant is 600 gal/min (136 m^3/h). Based on EPRI's computer modeling of the plant cooling process and chemistry, predictions indicate the same plant can safely reach 20 cycles of concentration; blowdown could be reduced by 440 gal/min (100 m^3/h) to 160 gal/min (36 m^3/h). In terms of evaporation ponds that cost $100,000 an acre and evaporate about 1 gal/min (0.23 m^3/h) per acre, that 440 gal/min cut would save the hypothetical plant $44 million. In terms of vapor recompression, which costs about $4.5 million to evaporate a flow of 100 gal/min (23 m^3/h), the reduction of 440 gal/min of blowdown would save $20 million.

EPRI is now attempting to establish the exact impurity levels a power plant can tolerate through a multiphase project on the treatment of recirculated cooling water. Cooling-tower water constitutes over 85% of the water used within a power plant and directly affects condenser performance. Later projects will focus on other plant subsystems.

The objectives, according to Chow, are to provide a verified design procedure for water treatment and quality control in condenser and cooling-tower circuits; a set of computer models that simulate both the cooling-tower process and the circulating-water chemistry and its control; and operational guidelines to ensure proper implementation of the design procedure.

When plant operators are able to establish the exact chemistry of recirculating waters, they should be able to operate up to specific chemical limits rather than within a conservative range. This should reduce the demand for makeup water, permit the consideration of lower-quality water as a supply source, and minimize dependence on costly chemical additives. Stearns-Roger, the prime contractor, is now coordinating the development of the engineering design methods for water treatment. Radian, Inc., is providing the modeling expertise to define and describe the cooling-system equilibrium water chemistry, the performance of treatment operations, and the general effects of chemical additives. Codification of these detailed design and performance computations into computer routines will offer the user, whether technical designer or plant personnel, the capability to evaluate treatment and operation alternatives.

As part of the project, Stearns-Roger's subcontractor, Resource Conservation Co., has designed and constructed a portable test facility to collect field information for qualifying the design methods and computer models. The facility consists of a miniature cooling tower, boiler, and condenser, as well as makeup and sidestream treatment units. It will circulate 100 gal/min (23 m^3/h) of water drawn from the same source as that of the power plant at which it is tested.

A broad range of situations will be evaluated, including plants that are troubled with calcium carbonate, calcium sulfate, and silica scaling; a plant with low total dissolved solids; a plant that uses treated sewage waste water; and a plant that uses brackish well water. The test facility began operation at Public Service Co. of Colorado's Comanche station in January and will continue testing over the next three years, spending an average of six months at each site.

Only a beginning

EPRI's ongoing projects and upcoming symposium are just a start toward perfecting the state of the art of zero discharge design, operation, and maintenance. There are many other areas that need to be researched before utilities will have zero discharge systems well in hand. The chemistry and biology of plant water is one such nebulous area; another is the effect of different fuel qualities on plant water. Chow, Jorden, and Maulbetsch emphasize the importance of continued water management research.

As environmental standards tighten, more and more utilities will be obliged to construct zero discharge power plants. Water supply is also decreasing in many areas of the United States, and as supply diminishes, zero discharge systems should become increasingly attractive. As water becomes scarcer, the quality of available water tends to drop too, so technologies that can deal with these lower-quality waters will be essential.

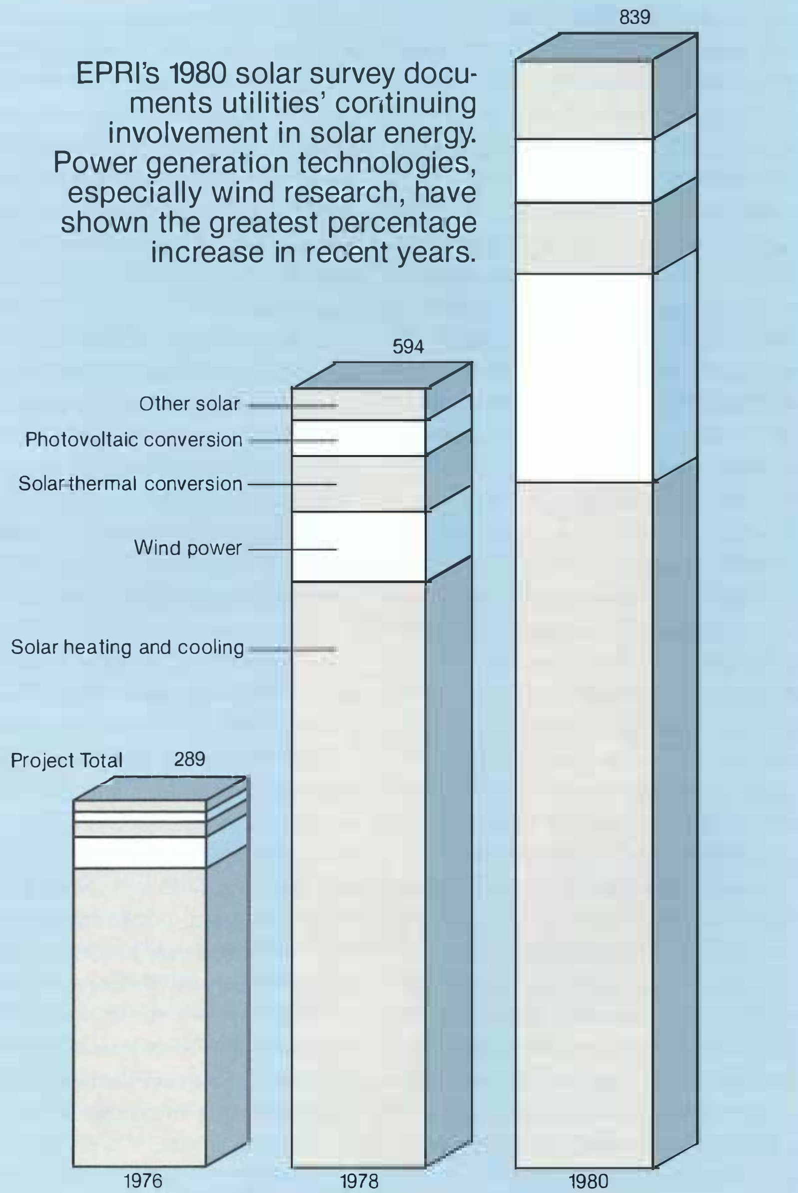
There are also some particularly pressing challenges ahead. Most of today's zero discharge plants are in the West, but more will be located in the eastern United States. The weather in the East presents special problems for designers of zero discharge systems. Because the precipitation there is greater than in the West and because temperatures are generally lower, evaporation ponds that work in the hot, arid West will be unsuitable for the East. New solutions will have to be developed.

Through diligent R&D, zero discharge systems can be perfected. "It's easier said than done, but it is possible to design and operate zero discharge plants that work well," concludes Jorden. "Careful attention through the whole process of design, construction, operation, management, and maintenance is all it takes." ■

This article was written by Nadine Lihach. Technical background was provided by Winston Chow, Roger Jorden, and John Maulbetsch, Coal Combustion Systems Division.

SOLAR UPDATE

EPRI's 1980 solar survey documents utilities' continuing involvement in solar energy. Power generation technologies, especially wind research, have shown the greatest percentage increase in recent years.



Data from the 1980 solar survey reveal that 236 utilities are involved in projects related to the use of solar energy, an increase of 31% over the number of U.S. utilities investigating solar technologies in 1979. The survey also highlights a trend that has been developing over the past few years: a growing involvement in solar power activities, as distinct from solar heating and cooling (SHAC) investigations. Almost half of the projects are funded by the utilities themselves as in-house work. Sponsorship of the remainder is distributed among government agencies, private sources, utility groups, and EPRI. Direct utility spending on solar projects has been estimated at $35 million for 1980; estimated total value of the projects is about $200 million.

As Edgar DeMeo, manager of EPRI's Solar Power Systems Program, comments, "One of the reasons utilities are involved in solar projects is to better understand how solar systems will influence their electricity supply networks. Results are now becoming available from investigations of SHAC systems. Solar power technologies, on the other hand, are only now entering the field test and early pilot plant phases during which information on performance and network impact is developed."

The increasing attention being paid to solar technologies is the result of many well-known factors: rising oil and gas costs, siting restrictions, and increasing environmental constraints. But one of the biggest problems facing utilities today is capital availability, and solar technologies, although capital-intensive, may have potential for alleviating this situation. Fossil and nuclear power plants are most economic in large sizes, in the range of 1000 MW. Yet it is extremely difficult for a utility to finance a large plant that may take over 10 years to move through the process of licensing and construction to startup. Capital must be committed for several years of the extended construction period, and in many cases utilities cannot begin to recover costs from their customers until plant startup. A solar plant, on the other hand, can be considerably smaller, and it may be possible to add capacity incrementally as a utility needs it. A typical solar-thermal power tower may have a rated capacity of 50 MW; large wind turbines have rated capacities of 1–5 MW and can be erected singly or in clusters.

Wind power

Among the solar power technologies, the one showing by far the greatest increase in utility involvement is wind power. An 80% increase in the number of wind energy conversion projects represents the most dramatic growth in interest of any technology reported in the 1980 survey. Nearly 40% of the utilities surveyed reported involvement in a wind energy project. This growing interest reflects the expectation that wind power is likely to be the first of the solar power technologies now under development to achieve commercial use. Its potential to supply power in utility systems will most likely be understood within the next five years, while that kind of information will probably not be available for the other solar power technologies until the end of this decade.

DOE's Large Wind Turbine Program involves 6 utilities as hosts for large wind turbine installations. An additional 24 utilities are candidates for future installations and are now collecting wind data in their service areas. The first of DOE's 2.5-MW machines, the most advanced in a series of horizontal-axis turbines developed under the program management of NASA's Lewis Research Center, began generating electricity last November at Goodnoe Hills in the state of Washington. Two more of these turbines, designed and built by Boeing Engineering & Construction, are currently being added to form a cluster that will feed power into Bonneville Power Administration's transmission system.

Several utilities are conducting their own major field test and pilot plant activities. And other projects entail small wind turbine field tests, integration assessments, and monitoring of residential, commercial, and agricultural installations. In all, 91 utilities are involved in a total of 152 identified projects.

Photovoltaics

The process of converting sunlight directly into electricity by photovoltaic, or solar, cells is still from ten to twenty times more expensive than conventional approaches to power generation. A combination of basic technological advances and market development is necessary to push costs down to competitive levels. The 50% increase in the number of reported projects since 1979 reflects a significant growth of utility participation in photovoltaics activities. Several utilities are helping to develop confidence in the technology by obtaining performance information and operating experience, often in cooperation with such federal programs as DOE's photovoltaic applications experiments. El Paso Electric Co., for example, is the subcontractor and cofunder of a project with the New Mexico Solar Energy Institute. The utility has recently completed a 20-kW flat-plate photovoltaic system that when operating most efficiently, can provide almost 90% of the power necessary to run the control computer at one of the units of its Newman station. The project, which uses commercially available conventional silicon cells, is one of a group of nine sponsored by DOE to obtain early operating experience with photovoltaic systems for industrial and commercial use.

Other utility projects are assessing how photovoltaic systems can best tie into a utility's total system. Still others are contributing to technology research and development.

Solar-thermal energy conversion

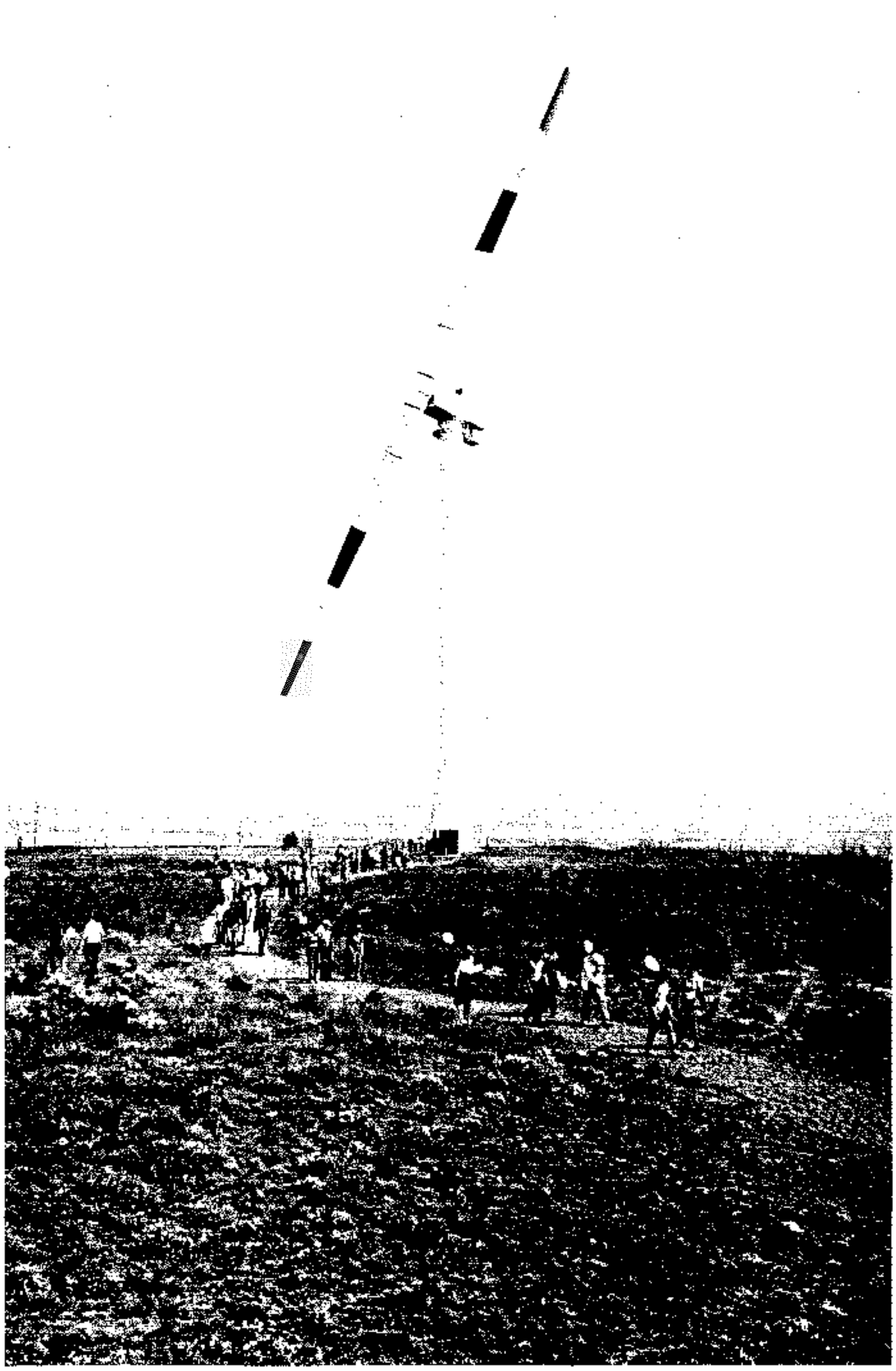
Because solar-thermal conversion requires relatively large installations, several utilities are participating in group projects sponsored by DOE, EPRI, or utility organizations. For example, the 10-MW (e) solar-thermal central receiver power plant currently under construction in southern California is being sponsored by DOE, Southern California Edison Co., the Los Angeles Department of Water and Power, and the California Energy Commission. An additional 13 utilities are represented on a project review and evaluation committee. The repowering of existing fossil fuel power plants by the addition of solar-thermal systems is also receiving attention because this approach could provide operating experience with system sizes between the 10-MW installation and future commercial plants. Such experience will be essential before commercial plants can be seriously considered. Seven utilities, most in partnership with a private engineering firm, have completed DOE-funded system design studies for hybrid repowering and are awaiting decisions on construction funding.

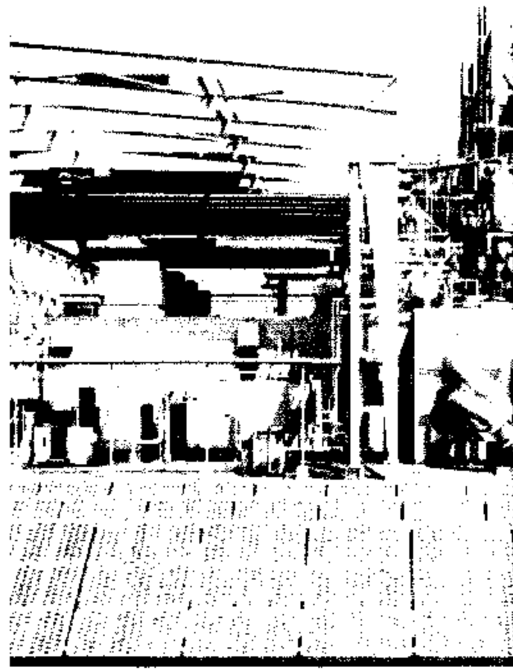
Solar heating and cooling

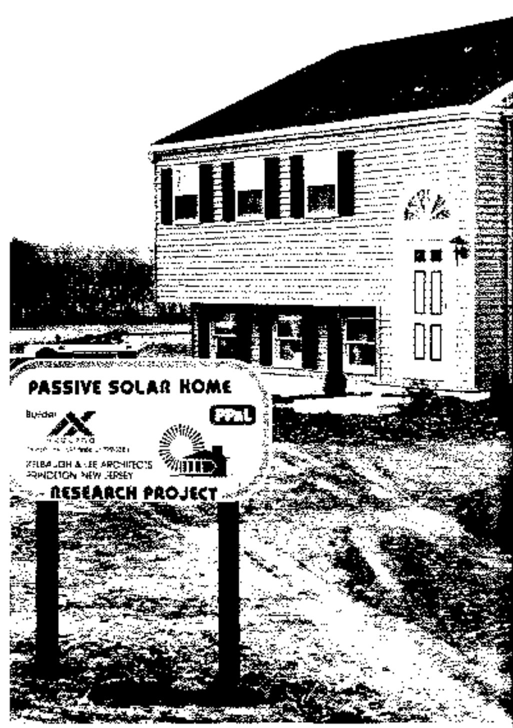
As in previous surveys, SHAC projects continue to represent the bulk of the utility solar projects, and their number increased somewhat during 1980. However, the percentage of identified utilities involved in SHAC projects declined from 85% in 1979 to 67% in 1980. It is important here to distinguish between passive and active SHAC technologies. Active systems involve placement of hardware, such as collectors and pumps, on a building. Studies begun several years ago on active systems are now providing information about system performance and potential impact on electricity networks; the number of these types of projects now appears to be declining. At the same time, involvement has increased significantly in passive solar projects, which focus on the basic architectural design of a building. Seventy-one passive solar projects were under way in 1980, compared with 49 in 1979 and only 15 in 1978. Many utilities are beginning to perceive passive solar technology's potential to reduce peak generating requirements, particularly those of residential customers.

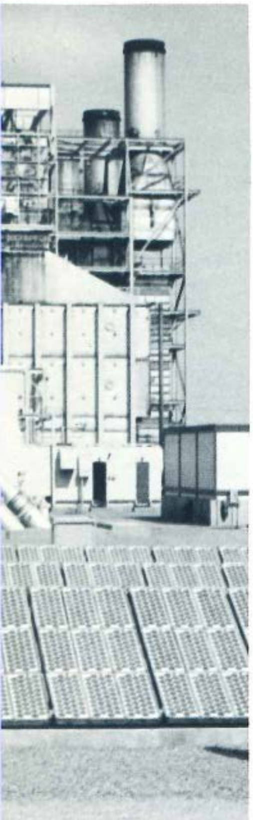
Pennsylvania Power & Light Co. is conducting a passive solar project involving six homes under construction in its service area. The project has been designed to reveal the most cost-effective combinations of passive systems, build-

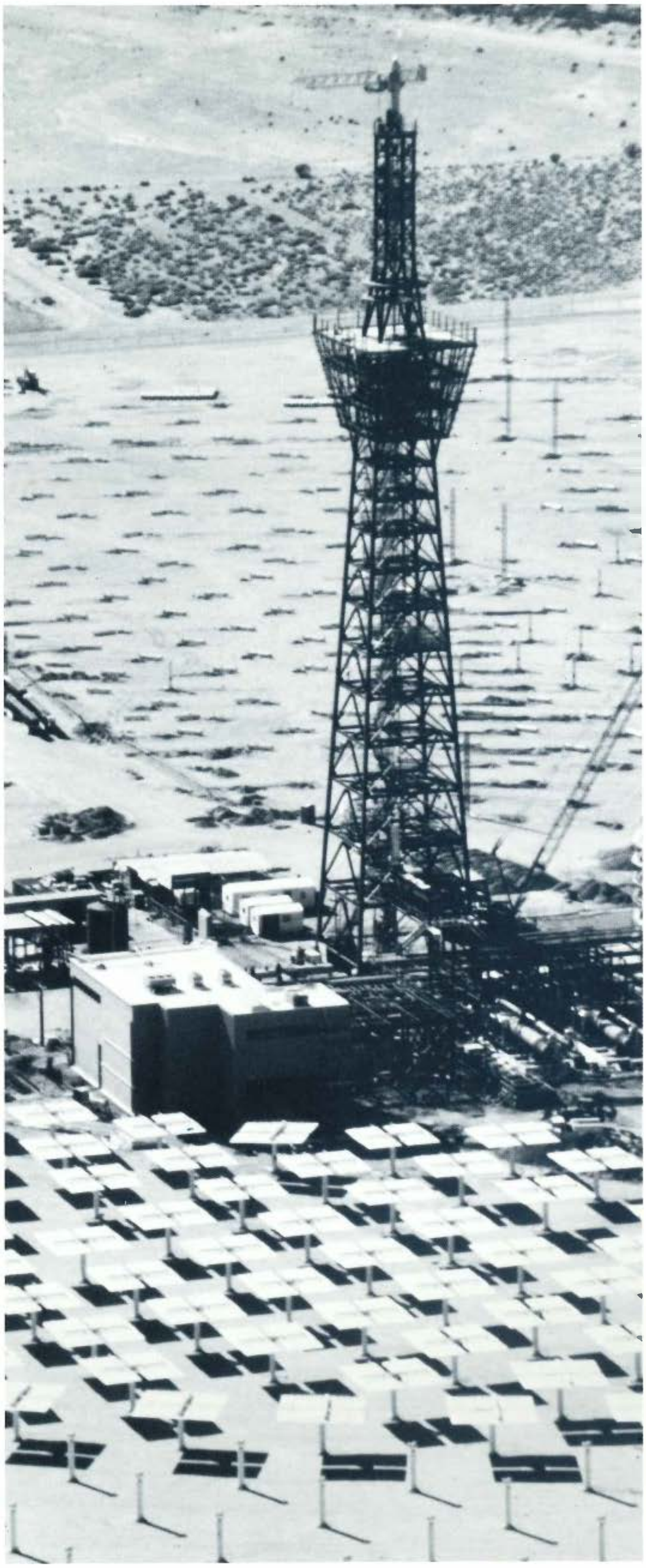
EPRI's latest survey shows the growing utility interest in solar power generation technologies in addition to the solar heating and cooling projects that have dominated R&D for years. Shown clockwise from left: one of three 2.5-MW wind turbines (the latest design in a series of DOE-sponsored wind machines) recently dedicated near Goldendale, Washington; a 2-kW array of photovoltaic panels being used to power a control computer at El Paso Electric Co.'s Newman station; the 10-MW solar-thermal central receiver power plant being constructed near Barstow, California, cosponsored by DOE, Southern California Edison Co., Los Angeles Department of Water and Power, and the California Energy Commission; and a solar home built by Pennsylvania Power & Light Co., featuring passive solar heating and cooling technologies. (Photos: courtesy of El Paso Electric Co., Southern California Edison Co., and Pennsylvania Power & Light Co.)











ing designs, and supplemental heating systems. The homes feature classic passive solar construction elements: air-lock entries; double-glazed, south-facing windows; mass walls; and sunspaces. Three of the homes contain a passive water-heating system as well. Several different types of supplemental electric space-heating systems are being used.

Biomass and other approaches

The number of bioconversion projects increased from 23 to 34, as integration assessment, system design, plant construction, and retrofitting continue. Fuel sources evaluated include waste wood, flax pellets, corn and wood cultivated for fuel, and peat. Several projects evaluated the production of alcohol, methane, or other fuels from biomass.

The remaining 4% of projects include process heat installations and feasibility studies, assessment studies, testing of components and systems for ocean-thermal energy conversion, and six DOE assessment studies aimed at estimating the potential for the development of several solar power technologies in various regions of the country by the year 2000.

The annual survey continues to be a valuable directory of individual utility activity and a public record of the commitment of the utility industry to the development and integration of solar technologies. In addition, it assists EPRI project managers in developing solar energy programs that are responsive to utilities' needs. *Electric Utility Solar Energy Activities: 1980 Survey* is now available (EPRI AP-1713-SR). In addition, EPRI has just published an information brochure, *Electric Utility Involvement in Solar Energy.* Along with a sampling of utility solar projects, the brochure contains brief descriptions of the various solar technologies and of the major issues in each approach. ■

This article was prepared by Margaret Laliberte, science writer. Data were compiled by Mary Wentworth; technical information was provided by E. A. DeMeo, Advanced Power Systems Division.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is in Conservation Strategy

Realignment is taking place among the major participants in energy conservation. The federal role is being elevated from mandatory prescriptions to broad policy guidelines, reestablishing the traditional link between the consumer and the energy delivery system.

Common to the many diverse motivations for conservation is a desire for a less wasteful, more productive use of energy. Once seen as the road to our [illegible], conservation is now emerging as a strategy for the wise use of energy—a strategy for enhancing economic productivity while preserving scarce resources. But significant shifts are taking place in the way conservation is to be brought about.

Until recently, the federal government's conservation effort has been focused on reducing dependence on oil imports by relying on regulations and demonstration programs to bring about or accelerate conservation. But under the Reagan administration, federally mandated conservation programs are likely to decrease as the government shifts its role and encourages the private sector to take a more dominant role in conservation.

The philosophy underlying the administration's position was indicated recently in congressional testimony by Frank DeGeorge, DOE's acting assistant secretary for conservation and renewable energy. "With rising energy prices," he said, "the need for government regulation and incentives, which were originally designed to stimulate domestic production or conservation efforts, has been reduced and in many cases eliminated."

Utilities have already begun to respond to the economic conditions. As S. David Freeman, chairman of Tennessee Valley Authority, says, "Federal initiatives or no, TVA will explore and pursue appropriate conservation initiatives, simply because they make sense for our customers and for our power system." And as Leslie C. Weber, manager of re-

search for Northern States Power Co., comments, "Government cutbacks will put a greater burden on the utilities that want to continue their conservation programs. In our case, we'll probably accelerate our conservation efforts."

The changing federal role

In an effort to speed conservation during the 1970s, the federal government relied on a series of legislative restrictions and inducements. The Public Utility Regulatory Policies Act (PURPA) established new rate-making standards and provided incentives for customer participation in electricity generation. The National Energy Conservation Policy Act (NECPA) set up the Residential Conservation Service (RCS) to oversee utility efforts to help their customers with energy audits and insulation retrofits. The Power Plant and Industrial Fuel Use Act (FUA) restricted utility use of petroleum and natural gas. And the Energy Conservation Standards for New Buildings Act required DOE to institute building energy performance standards (BEPS) that would limit the total amount of energy a new building could consume. (BEPS affected utilities particularly by requiring calculations that penalized the use of electricity.)

The new approach will shift emphasis away from federally mandated implementation to traditional, well-established local and state delivery mechanisms (e.g., utilities, manufacturers) under the guidance of a local regulatory authority.

In an interview, DeGeorge spoke about the new relationship that will be developing between utilities and the federal government as a result of the new policies. "You'll see a 180° change in approach. This president feels strongly that it's not our job to interfere with private enterprise. Utilities will have to make their decisions on the basis of the technology available." Thus utilities will be expected to continue providing energy audits and encouraging cogeneration without federal prompting and to conduct demonstrations of new energy technologies and energy-efficient industrial processes without federal funding.

Congressional concerns

Some of these proposed budget cuts, however, are likely to raise congressional concerns. Representative John Dingell, chairman of the House Energy and Commerce Committee, has said the federal government should continue to push conservation and alternative energy programs and, in particular, to use legislation like PURPA to stimulate state action. Representative Richard L. Ottinger, chairman of the committee's Energy Conservation Subcommittee, has predicted Congress will balance the administration's proposed energy budget. In an interview, Ottinger's aide Michael McCabe explained the philosophy and political strategy behind this move. "Our philosophy is that the best short-term effort should be in conservation; it's the least-cost strategy as well," he said. "Congressman Ottinger will use this platform to educate the administration."

Nevertheless, the need for some federal involvement was stressed in congressional testimony given by Thomas Stelson, DOE's assistant secretary for solar and conservation under the Carter administration. "Energy conservation involves complex institutional barriers which prevent the free enterprise mechanism from working effectively and requires leadership, coordination, and stimulation by government."

The utility industry position on various specific issues in this developing congressional controversy is still being discussed. However, on such points as opposition to mandates, there seems to be unanimity. As Jack Russell, vice president of Long Island Lighting Co., told Ottinger's subcommittee in testimony on behalf of Edison Electric Institute, "Mandatory energy conservation programs are like requiring everyone in the U.S. to wear size $8\frac{1}{2}$ shoes just because the average size for the U.S. is $8\frac{1}{2}$. Some people will get blisters and others will get bunions. While the RCS program is well intentioned, its cost-effectiveness is questionable."

Already there are hundreds of conservation experiments being conducted by utilities, and in interviews with several utility executives and utility trade association representatives, a broad willingness to further validate the more promising conservation programs was expressed, even if federal sponsorship is eventually withdrawn. Don Denton, vice president of Duke Power Co., said government cutbacks "will allow us to move ahead faster, since conservation and load management programs are always in the best interest of both stockholders and rate payers."

Low-risk, high-payoff programs, such as energy audits and weatherization, will most likely go forward, quite possibly at a faster pace. However, longer-term technology development and demonstrations could be affected by this shift in federal emphasis. Of particular concern to municipals and others is the impact on dispersed generation (e.g., fuel cells, photovoltaics), which is viewed as a potentially attractive supply option that can be brought on-line in smaller increments and with less lead time.

Importance of the utility role

Electric utilities have a vital role in helping improve the wise use of energy in the United States. Electricity is critical to national conservation strategy because of its unique ability to substitute abundant energy resources (coal, uranium) for scarce ones (oil, gas) and to improve the efficiency of energy use through the introduction of new technology and automation. Indeed, several industrialized countries have adopted policies of enhanced electrification as a key element in their response to the oil crises of the 1970s.

Although the United States has not recently emphasized a policy of electrification, the economy's natural response to changes in the cost and security of supply of energy resources (especially of oil) has nevertheless been a clear and sustained turn in this direction. While the total energy consumption needed to sustain a unit of growth in the gross national product has fallen sharply since 1973, the amount of electricity required per unit has risen. This shift from scarce to abundant fuels via electricity must be efficiently accomplished at reasonable cost.

To avoid insufficient power generation, electricity conservation requirements will be even greater in the future. EPRI studies estimate that conservation requirements in the year 2000 will be 1.3×10^{12} kWh for the industrial sector and 0.6×10^{12} kWh for the residential, commercial, and transportation sectors. That would amount to a 62% increase in the output produced by each unit of electric energy for all industrial processes, 9% improvement in the efficiency of all electric appliances, 40% improvement in the coefficient of performance (COP) of heat pumps (i.e., the ratio of heat output to work input), 44% improved COP for air conditioning, and a greater commitment to upgrade home insulation.

Utility conservation strategy

Despite conservation efforts, new power plants need to be built. But utilities are also vitally interested in conserving capital. Thus, to minimize the high cost of new generation capacity in the near future, many utilities are trying to increase the use of baseload plants through load management and to temper demand growth by improving the efficiency of electricity end use.

Such conservation—wise use—of electricity can have important long-term impact on electric utilities. Sustained growth of their business depends on keeping the cost of electricity competitive so it can replace costly oil imports.

Traditionally, utilities have been very successful in increasing the efficiency of electricity generation and distribution, and these efforts are continuing. There seems to be general agreement that the largest efficiency gains in the future are to

National policy initiatives currently under review. Changes are anticipated in several end-use sectors.

	Information	Incentives	Pricing	Regulation
Residential/ Commercial	• Residential conservation service • DOE advertising/information system (low cost/no cost program) • Action grants • Institutional conservation program • Energy extension service	• Conservation/renewables tax credits • Weatherization program	• Deregulation of oil/natural gas • Electricity rate standards (PURPA)	• BEPS • PURPA (buy back) • Time-of-sale building efficiency standards • Appliance efficiency standards
Industrial	• Voluntary standards • DOE information service	• Tax credits for cogeneration, renewables	• Deregulation of oil/natural gas • Electricity rate standards (PURPA)	• Voluntary standards • Fuel Use Act regulations • PURPA buy back standards
Transportation	• DOE information programs (e.g., driver awareness, van pools) • EPA mileage information	• Gas-guzzlers tax • Inclusion of EVs in CAFE standards • Tax exemptions for gasohol	• Taxes on gasoline • Deregulation of oil	• CAFE standards • 55 mph speed limit • Proposed emergency regulations

be made in the end use of electric energy. The utility response to the need for conservation is based on three elements.

- Stimulation of the development, demonstration, and acceptance of technologies and practices for more efficient use of electric energy
- Development of technologies and systems to improve electric utility load management, thereby reducing and/or deferring the need for new capacity
- Development of end-use technologies and systems that allow cost-effective substitution of electricity in energy end uses currently dependent on increasingly scarce fossil fuels

A research mandate

Improving productivity of in-place equipment and the efficiency of all energy-related activities from mining to end use is all-important to the electric utilities. EPRI, in its role as the RD&D arm of many of the country's utilities, has developed a strong program focused on supply technology that parallels utility concerns for an adequate economic and environmentally acceptable supply of power. As the increased importance of better utilization of electric energy and electric equipment through load management emerged and as the importance of electricity in substituting for oil and gas became fully appreciated, EPRI began to develop and put in place three elements of its R&D strategy: efficient electricity use, improved load management, and efficient substitution for scarce resources.

From the outset of building this program in EPRI's Energy Utilization and Conservation Technology Department, it was clear that these elements were not of equal importance to all utilities. Utility conservation emphasis and decisions are necessarily influenced by local or regional customer energy use patterns, projected demand growth, reserve capacity, load factors, fuel mix, and the availability of capital. From 1980 to 1985, for instance, migration will be responsible for much of the difference in annual load growth forecasts of 2.59% for utilities in the Northeast, 5.25% in the South Central region, and 4.15% in the Far West. On the one hand, a utility may have sufficient reserve generating capacity on-line to meet any peaks of demand but not have the primary energy resources available to use that capacity. Or the primary energy resource might be oil, available but priced at a premium. Or a utility might be able to supply all the baseload electric energy requirements of its customers but not have sufficient generating capacity to meet peak demands.

EPRI's contribution

The national need, therefore, is for more productive use of energy resources, with emphasis on reducing oil imports; the customer's need is for reliable and reasonably priced electricity; and the electric utility's need is to coordinate the growth of kilowatt use and the ability to supply. These needs have prompted utilities to place increasing importance on energy end-use activities and conservation. Many utilities have begun to redefine their traditional role to one of overall delivery of energy services. This shift in planning emphasis by utilities to closely examine load shifting, increasing efficiency, and substitution is being paralleled by research programs at EPRI.

Three EPRI divisions are involved in helping the utility industry carry out its mandate in conservation R&D. The Energy Analysis and Environment Division conducts conservation and demand analyses, studies rate design, and develops analytic methods and data. The Electrical Systems Division is responsible for improving conservation along the power transmission and distribution system. And the Energy Management and Utilization Division is responsible for the development of conservation end-use technologies. R&D on conservation end-use technology is conducted by this division's Energy Utilization and Conservation Technology Department. Its program objectives recognize the widely varying needs of the customers and the utilities and are aggregated into the following sectors.

Residential and commercial applications

The customers in this sector represent 99% of all customers served and use 57% of all electricity. They are also the primary cause of the sharp daily and seasonal peaks in electricity demand that are often served by peaking generators fueled by imported oil. This problem is particularly serious in regions where a summer peak demand for air conditioning is not balanced by other loads, such as electric heating.

Conservation in this sector thus demands end-use technology that can use electricity more efficiently, offer load management options, and stimulate efficient substitution of electricity for imported resources, all of which will help utilities smooth out peaks of demand.

The EPRI research response has been to take a lead role in development of advanced heat pumps; to help find ways of improving the thermal integrity and energy use management of buildings; to develop and evaluate thermal energy storage and other load management technologies; and to conduct research on utility-compatible solar heating and cooling (SHAC) systems. Specific goals include development of more efficient heat pumps with reduced demand on utility systems, cool storage that can help reduce summer air conditioning peaks, and SHAC systems that can help utilities defer the building of backup generating capacity.

Industrial applications

Industry relies on petroleum and natural gas for 70% of its energy needs and uses 37% of all electricity. Since energy is a major element of the production process, improvements in electric energy utilization efficiency and the substitution of electricity from coal, renewables, and nuclear through the introduction of efficient alternative technologies are leading strategies for increasing productivity and holding down costs. The efficiency targets set in 1972 by the federal government for 10 major industries have been substantially met in reducing the energy required to produce a unit of output by 17%. Future improvements are likely to involve more ambitious efforts to make industrial processes more productive and save on energy costs, often using electricity as the key. EPRI is exploring formation of an industrial users group to promote consultation between utilities and industrial consumers on conservation R&D opportunities of mutual interest and, in the longer term, the active participation of industry in a coordinated R&D plan in selected generic areas.

At present, EPRI's approach focuses on the development of new or improved electrification and thermal energy management technologies and on how to expedite their commercial introduction; the development of a methodology for assessing dual energy use (cogeneration and district heating) systems, giving explicit consideration to utility coordination perspectives and the identification of promising options; the fostering of new devices, such as power transistor technology, microprocessor controls, and variable-speed drive devices; and the achievement of major energy efficiency improvements by the use of improved or alternative processes.

Electric transportation

Transportation is the sector most dependent on imported oil and most vulnerable to supply interruptions. It accounts for 54% of the petroleum consumed in the United States. Electrification could replace a significant portion of this oil consumption.

Because electric vehicles (EVs) have the potential of being recharged during off-peak hours and thus could be a factor in load leveling for utilities (thereby reducing the cost of power generation), EPRI has focused its activities on testing EV components to characterize their performance and identify key areas of improvement. Through the EPRI–TVA EV demonstration projects, an EV performance data base is being established to quantify power train, battery, and battery charger performance in a utility setting. This demonstration has resulted in identifying critical improvements required in battery and battery charger components. As new battery systems are made available, advances in their performance are being validated and specific improvements funded. Because the battery charger has been a major contributor to EV inefficiency and line pollution in the utility grid (poor power factor, harmonic injection, and magnetic interference), EPRI is developing specifications and advanced designs that will increase charger efficiency and reduce negative effects on the utility system.

EPRI's practical EV demonstration experience is being utilized in the development of analytic models to assess the future impact of large numbers of vehicles on the generation and distribution of electricity. These analytic methods are directly assisting utilities in their formulation of policies to support the introduction of EVs and to develop load management strategies.

EPRI recognizes that utilities could be an early market for a reliable electric work vehicle. The EV testing, component development, and analytic methods are focused on implementing a strategy for an industrywide purchase of a large number of improved EVs. This joint purchase could provide the impetus for the demonstration of reliable and practical EVs and the initiation of their widespread use.

Future conservation efforts

It is likely that EPRI, the utility industry, and manufacturers will be called upon to fill some of the gaps left by the shift in emphasis of the federal R&D conservation programs. Determining which specific areas may be involved will, of course, have to wait until the congressional budget process has been completed and until the utilities involved can reassess their conservation strategies.

Already, however, technology transfer is becoming a dominant theme in EPRI's expanding end-use program. The entry of the Institute into areas of end-use research introduces the challenge of reaching a much larger audience. Rather than reporting results of conservation R&D only to a limited, relatively sophisticated utility audience, EPRI will need to work with utilities to speed new technology applications to millions of consumers and their engineers, architects, and other customer support groups. To help expedite this new technology transfer activity, an ad hoc utilization transfer committee has been proposed, chaired by EPRI and consisting of representatives of the three major utility trade associations. However, this committee would represent only one imaginative way of expanding technology transfer, which requires a pluralistic approach.

A perspective on the importance and rapidly changing climate of conservation research is offered by Fritz Kalhammer, director of EPRI's Energy Management and Utilization Division. "It is important to remember that even in 1976—well into the energy crisis times—conservation was barely mentioned. When it was discussed, the issue often created controversy. Today, properly interpreted as the wise use of energy, conservation is universally accepted as a key element of national and global energy strategy. Its importance is to buy time for implementing the supply strategies and systems that ultimately should ensure energy security for all of us. But conservation won't happen by itself. Part of the responsibility of a free market utility system, freed from conservation programs mandated by the federal government, is to conduct the necessary R&D to optimize energy use. Our EPRI conservation research has tried to respond to this need." ■

This article was written by John Douglas, science writer. Technical background information was provided by Orin Zimmerman, director of the Energy Utilization and Conservation Technology Department.

Energy Focus of the Reagan Administration

The quest for an energy policy under President Reagan might begin with the Department of the Interior and Secretary James G. Watt. Through the opening of federal lands and regulatory reform, DOI is actively encouraging domestic energy development.

Before the Energy Research and Development Administration or the Department of Energy, before the Federal Power Commission or the Federal Energy Regulatory Commission, there was the Department of the Interior. The federal government's involvement in energy development actually began in DOI—it is over 130 years old and has responsibility for most of the federally owned public lands and the resources on those lands. Through its Bureau of Reclamation, the agency built large dams for hydroelectric power and began to distribute electricity throughout the West. To facilitate the distribution of this electricity, federal power marketing agencies were created and administered by DOI.

The agency also started the Office of Coal Research, which began the government's first research into coal conversion technologies. And in the early 1970s, the National Petroleum Council, an industry advisory board to the Secretary of the Interior, undertook the first comprehensive study of the energy outlook for the nation. NPC published a report in July 1971, *U.S. Energy Outlook: An Initial Appraisal 1971–1985,* that provided the groundwork for subsequent investigations of the U.S. energy situation.

Although many of DOI's energy functions were transferred to the new Department of Energy in 1977, DOI still remained important to energy policy and the utilities as the guardian of the nation's natural resources. Many of the country's public lands have the potential for coal, gas, and oil production. However, in the past these areas have been increasingly placed off limits for energy development. As will be seen, this may be changing.

The new administration has brought in a new Secretary of the Interior who, Washington energy observers say, may change many of the old attitudes of the agency. James G. Watt, a Denver attorney and a former vice chairman of the Federal Power Commission, has stated his intention to expand domestic energy production and to open the public lands for resource exploration. If Watt has his way, a new national energy policy may be in the offing and DOI will be the federal agency to watch in the months ahead.

The New Secretary

Fresh from his confirmation as secretary of DOI, in February Watt spoke before the House Committee on Interior and Insular Affairs and signaled a new era in natural resource development. "I want the federal and state governments to strike a balance between the development and the protection of our natural resources. We can have reasonable development and protection of our natural resources and preserve our natural environment if we are given an opportunity to phase in, with proper safeguards, the expansion being demanded by the nation."

By opening nonpark federal lands to mineral and energy development, Secretary Watt hopes to accomplish this expansion needed by the nation. And in consonance with the philosophy of the

Watt

Reagan administration, he will encourage this increased development through a program of regulatory reform. "I plan to end unnecessary and burdensome regulations now frustrating America's mineral development programs, the balanced management of our nation's resources, and the nation's economic recovery itself." Some DOI policies and regulations to be reviewed by the new administration include modifying the criteria under which public land is declared unsuitable for mining, determining how much land in Alaska is available for energy development and how much for wilderness, easing regulations governing competitive lease sales for coal on federal lands, limiting federally supplied water to landowners, and accelerating offshore oil and gas leasing on the outer continental shelf.

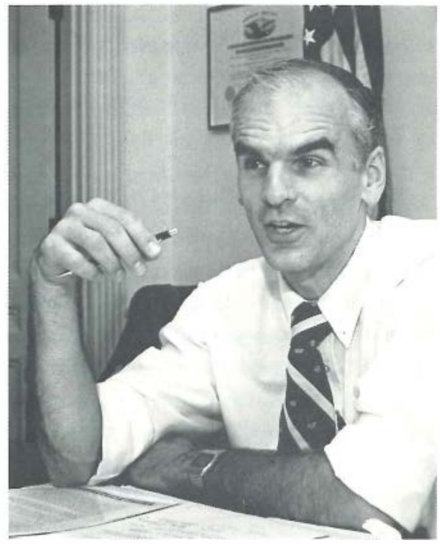
What is meant by this new era of open federal lands and mineral exploration? It may be too soon to tell how much regulatory change will occur, as many of these regulations will be challenged in the courts by those opposing Watt's views. But what is clear is that the new administration is committed to domestic energy production and Watt will be a key factor in implementing this commitment. A closer look at DOI and the offices where these regulations are administered should help in understanding what the future holds for improved energy development.

The Agency

Created by an act of Congress March 3, 1849, DOI has responsibility for most of the nationally owned public lands and natural resources. The agency also assesses the nation's energy and mineral resources, exercises the nation's trust responsibility for the American Indians who reside on or near more than 50 million acres of reservation lands, and has administrative responsibilities for the American territories of Guam, American Samoa, the Virgin Islands, and the Trust Territory of the Pacific Islands.

DOI is divided into six organizational units each headed by an assistant secretary: Policy, Budget, and Administration; Energy and Minerals; Fish, Wildlife, and Parks; Indian Affairs; Land and Water Resources; and Territorial and International Affairs. Of these six units, the unit for energy and minerals and the unit for land and water resources have the most program areas of relevance to the electric utilities.

The current Under Secretary of DOI, Donald Hodel, a former administrator of the Bonneville Power Administration and a former member of EPRI's Board of Directors, explains further the relationship between the agency and the utilities. "The Assistant Secretary for Energy and Minerals has responsibility for the Office of Surface Mining, a direct factor in the cost of mining coal and therefore the cost to the consumer; the Bureau of Mines is responsible for underground mining safety; and the U.S. Geological Survey is important in oil, gas, and coal evaluations and searches. Much of what the utilities and their suppliers do and need, or want to do, is directly affected by these offices and bureaus," Hodel said. "The same is true of the Bureau of Land Management under the Assistant Secretary for Land and Water Resources. Most of the nearly half a billion acres owned by the federal government is managed and controlled by the Bureau of Land Management. Coal, oil, gas, oil shale, tar sands, and the like are to be found on that land."



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As with all the other federal agencies, DOI is streamlining its programs as part of the president's economic recovery program. In March Watt reduced DOI budget requests to $5.94 billion in FY81 and to $5.75 billion in FY82. The budget figures represent reductions of $383 million in FY81 and $877 million in FY82 from the Carter administration budgets for the same two fiscal years. When announcing these budget cuts, Watt commented, "President Reagan and I are committed to a fundamental change of course. We have concluded that massive reductions in the budget, together with the streamlining of programs and the elimination of excessive regulations, are necessary to improve the state of the economy."

In line with this commitment to streamline the agency, two program areas under the Assistant Secretary for Energy and Minerals are destined for some changes.

Reform in the Bureau of Mines

Established in 1910 and reporting to the Assistant Secretary for Energy and Minerals, the Bureau of Mines (BOM) is the federal government's principal mineral technology and information agency. One of its missions is to improve mineral technology applications and encourage their use in commercial mineral operations. The technologic and analytic programs of BOM touch on the full range of mining and mineral processing operations. BOM also manages a computerized storehouse of information about mineral resources and reserves worldwide.

As required by the Mining and Minerals Policy Act of 1970, the Secretary of the Interior must make an annual report to Congress on how well the country is prepared to supply essential minerals from domestic resources. BOM, therefore, participates with the U.S. Geological Survey in mineral assessment of national lands under consideration for designation as parkland, wildlife refuges, and wilderness areas. This work helps Congress decide how the lands should be used.

In April of this year Watt testified that it is his intention to move aggressively to implement a national minerals policy. To that end, Watt has redirected $8.6 million in BOM for the recovery of strategic and critical minerals. Reduction in two areas of research is proposed: mine health and safety, $5.2 million; and minerals environmental technology, $2 million. The total proposed revised BOM budget is $142.7 million, a reduction of $7.8 million from Carter's budget.

Watt also stated that the nation's strategic and critical mineral stockpile offers a backstop for defense and other emergency requirements. As vital as an adequate stockpile is to the defense of the nation, the best answer to long-term stable minerals availability is domestic production. According to Watt, "For every pound of mineral productive capacity we add domestically, the stockpile goal can be reduced by three pounds. In the face of current budget restraints, that concept is critical."

In the area of environmental research, BOM conducts an active program to demonstrate technology for repairing environmental damage from past mining operations. In cooperation with the Office of Surface Mining, BOM is involved in mined-land restoration, subsidence control, and fire fighting in abandoned mines. This brings us to another DOI office that will feel regulatory changes under the new administration: the Office of Surface Mining (OSM).

A New State Emphasis

Created by the Surface Mining Control and Reclamation Act (SMCRA) of 1977, the Office of Surface Mining (OSM) is charged with controlling the surface effects of coal mining and correcting the damages mining has done in the past. It also sets minimum national standards for surface coal mining operations, assists the states in developing and implementing regulatory programs of their own, and promotes reclamation of previously mined areas.

SMCRA requires that each state set up its own mining regulatory program under minimum federal standards. If the state's program is approved, it achieves primacy (control) and the federal government assumes an assistance and monitoring role. If a state's program fails to obtain approval, OSM may implement a federal program. Although the intent of OSM's program is to assist the states in developing their programs by providing technical assistance, there has been much criticism of the attitude and restrictive approach taken by OSM in the first few years of its existence.

A new emphasis on helping the states is in line with Watt's plans for reducing regulations in OSM. As Andrew Bailey, acting director, stated before the House Subcommittee on Appropriations, "The Office of Surface Mining's future role will be assisting the states and program evaluation, not dictating the nuts and bolts of how progress is made. The states can rectify abandoned mine land and water resource problems, crack down on violators, and make sure the environment is protected and the land is reclaimed. They can do it and get on with the job of meeting our energy needs."

Reflecting the intention to stress state primacy, the funding for federal regulatory enforcement and assistance programs in the proposed budget for OSM has been reduced from $44.4 million to $33.7 million. The transition from initial direct federal enforcement to a monitoring position as states begin to achieve primacy makes possible, according to Bailey, the large reduction in the federal inspection force, a reduction of nearly 56% in FY82 from the FY81 level. The total proposed budget for OSM is $179.8 million, a reduction of $66.6 million from the Carter budget. The largest increase in the proposed budget is for state reclamation grants for abandoned mines—a total of $70 million is being requested for these grants, which is a large increase from the $29 million in FY81.

In February Watt stated that "the Office of Surface Mining is one of the department offices responsible for much of the excessive, counterproductive regulation." Watt therefore directed Bailey to review and recommend elimination or revision of counterproductive regulations that are inconsistent with the statutes and the intent of Congress. OSM regulations singled out for early review by the new administration include those governing strip mining techniques and the reclamation of mined lands.

Water and Power

The three program areas under the Assistant Secretary for Land and Water Resources—Water and Power Resources Service, Office of Water Research and Technology, and Bureau of Land Management—will also be streamlined.

The Bureau of Reclamation was reorganized as the Water and Power Resources Service (WPRS) in 1979. It is charged with the broad responsibility of water and power resource management by enhancing the public's understanding of the management of water and renewable energy resources.

The Bureau of Reclamation was originally established to reclaim the arid and semiarid lands of the western states by conserving and supplying irrigation water, but as the bureau's responsibilities continued to grow, it began to manage multipurpose water projects, including the use of hydropower. WPRS continues to manage the agency's 50 hydroelectric plants, including the Hoover, Grand Coulee, Buffalo Bill, and Hungry Horse dams. These hydroelectric projects had a total installed capacity of 10.5 million kW and produced 43.3 billion kWh of energy in FY79. Production of an equivalent amount of energy from thermal power plants would have required 73 million barrels of oil. The electricity generated from hydro projects is transmitted and marketed by the Bonneville Power Administration (BPA) and the Western Area Power Administration (WAPA), now agencies of DOE. "Grand Coulee Dam is the backbone of the generation for the Federal Columbia River Power Systems," says Hodel, "It is the 'granddaddy' in size and low cost. Each of the 30 federal dams is important to BPA and the region and most of them are Corps of Engineers' dams, but the supply would have been much less and the price much higher without Grand Coulee."

A portion of the revenues earned by WAPA from the sale of the power and water is returned to the U.S. Treasury. BPA, under a self-financing act passed in 1975, has authority to retain and use its revenues for its operation and is required to repay with interest the federal investment in transmission and generation on its system.

In keeping with the national effort to improve the energy resource base, WPRS has been studying alternative energy sources, such as solar and wind. Feasibility studies of a large wind farm generating station near Medicine Bow, Wyoming, are part of this program, in addition to a study on the integration of wind power with hydroelectric generation.

In the area of engineering, research is designed to improve the efficiency and reliability of electric power generation, transmission control, and stresses in turbine shafts. The emphasis of the work in automatic control systems is aimed at identifying and implementing means to improve the performance of hydroplants, enhance system stability, and increase the effectiveness of available control systems.

WPRS funds will be reduced by $64 million in the proposed FY82 budget. Funds to initiate work on additional hydroelectric power generation at six existing sites will continue, as will the dam safety initiative. In his briefing on the budget, Watt explained that "the Water and Power Resources Service will continue to seek out well-planned new investments in the nation's resource base. All current construction projects will be continued, but acceleration of construction schedules and initiation of new projects will await an improved national economic situation."

Water Research and Technology

Another branch of the Land and Water Resources unit is the Office of Water Research and Technology (OWRT). Programs under this office are directed toward identifying existing and anticipated future water problems and supporting research to prevent or solve those problems. The Water Research and Development Act of 1978 provides a means for the Secretary of the Interior to ensure that water of sufficient quality and quantity will be available to meet the nation's continued economic growth and increased energy development.

Fifty-four water resources research institutes have been created under the act and are located at state land grant universities across the country. The institutes conduct and encourage basic and applied R&D and develop statewide programs for resolving water problems. In Texas, for example, the institute sponsored a project to increase overall water use efficiency in agricultural production and to minimize energy consumption through new concepts in irrigation system design and development. The new irrigation system that resulted from the research greatly reduces water and energy use for row-crop irrigation.

Yet the days of OWRT may be numbered. Under the revised federal budget, the administration has proposed to eliminate funding for OWRT and the Water Resources Council. Explaining this decision, Watt stated, "In this era of fiscal austerity, many of the functions of the Office of Water Research and Technology should properly be the responsibility of the states and private industry." A new office of water policy would be created to advise the Secretary of the Interior and to provide greater coordination with the states on water issues.

The new office of water policy would work in a framework of state and federal cooperation, but the emphasis will be on respect for state water rights and on each state's management of its own water resources and financial participation in water resource projects. The proposal to do away with OWRT includes withdrawing a proposed FY81 supplemental request of $22.9 million, a FY81 rescission of $11.8 million in contract, grant, and other funds, and elimination of the FY82 request for $32 million—a total savings of $66.7 million. To establish an office of water policy, the revised budget allows for funding of $2.5 million.

Changes in Land Use

Also administered by the Assistant Secretary for Land and Water Resources, the Bureau of Land Management (BLM) has responsibility for the 470 million acres of public lands in the nation. These lands contain some of the country's most spectacular scenery, as well as some of its most desolate areas, in which will be found many fossil fuels and minerals. Under the Federal Land Policy and Management Act of 1976, BLM received a mandate from Congress to administer the public lands and their resources. The lands are to be retained in federal ownership and managed under multiple-use principles for the public interest. "Every utility seeking western coal has been and will be affected by BLM policies on access to the public lands. We are committed to opening that access where appropriate and enabling responsible, timely, and predictable development of needed fossil fuels," said Hodel.

BLM plays a major role in the nation's ever-increasing search for new energy resources through offshore oil and gas leasing, as well as programs directed at increasing coal supplies and the development of oil shale and geothermal resources. In keeping with the new administration's emphasis on increasing use of domestic resources, the proposed BLM budget (compared with Carter's January 1981 budget) streamlines energy leasing activities and includes an increase in funds for offshore oil and gas leasing and management and an increase in onshore oil and gas leasing operations. However, the total revised FY82 budget for BLM's operating programs is $388.3 million, or $35.4 million below the proposed amount in the Carter budget.

BLM may play an important role in the opening of public lands for mineral and energy development. In testimony before the Energy and Mineral Resources Subcommittee of the Senate Committee on Energy and Natural Resources in April, Watt stated, "With management responsibility for both fuel and nonfuel minerals on all public lands, I intend to critically review all past and proposed public land use restrictions. I will oppose single-use designation of public lands if there is evidence that withdrawal means a significant loss of resources to the economy." Single-use designation means that the federal lands are classified as wilderness areas and cannot be opened for energy development. Multiple use means that a compatible mix of activities can occur on federal lands, for example, mineral excavation and logging.

At the Senate hearing Watt explained that he is considering a new public lands policy within DOI that would ensure the application of the multiple-use concept. He added that he is also considering the possibility of legislation to statutorily release multiple-use lands determined under the Federal Land Policy and Management Act to be unsuitable for wilderness. Watt indicated he is reviewing provisions permitting the exploration and development of minerals within the wilderness system under stringent environmental constraints. In his testimony he made it clear, however, that there will be no attempt to open existing national park lands to mineral exploration and development because these lands must and will be fully protected.

BLM will also play a role in the new five-year offshore oil and gas leasing program announced in April by DOE Secretary Edwards and DOI Secretary Watt in order to help achieve early leasing in high-potential areas. The accelerated program would make more acreage available for offshore leasing and cut the time that is now required for leasing in promising frontier areas. At a briefing announcing the accelerated program, Watt stated, "The Outer Continental Shelf Lands Act places on the federal government an affirmative responsibility to obtain for the public the benefits of oil and gas resources located offshore. The law intends that all areas with oil and gas potential will contribute to the nation's energy supplies."

To help in the identification of federal regulations that could be modified, two government task forces have been created. The Presidential Task Force on Regulatory Relief, chaired by Vice President Bush, will target specific regulations for early review by the administration. Watt recently announced the formation of another task force (under the cabinet-level natural resources group he chairs) to study the rate of U.S. energy development. Assistant secretaries from Interior, Energy, Transportation, and Defense will be on the committee and will identify impediments to energy development and suggest ways to remove them. Under the guidance of the new Secretary of the Interior, the road to increased domestic energy production may be an easier road to travel. ■

This article was written by Christine Lawrence, Washington Office.

Solar-Fossil Experiment Launched

Thirteen electric utilities will participate in an advanced solar-thermal power plant experiment.

A group of electric utility companies, serving customers in 12 states, has recently been formed to assist in assessing an advanced solar-thermal power generation experiment being funded by EPRI. The experiment will demonstrate a hybrid system that generates electricity from solar energy when the sun is shining and from fossil fuels when it is not.

The experiment will be designed, constructed, and operated under an EPRI contract with Boeing Engineering & Construction; it will be conducted at DOE's Central Receiver Test Facility near Albuquerque, New Mexico. Public Service Co. of New Mexico will be the lead utility participant. The 12 other participants are Arizona Public Service Co.; Bonneville Power Administration; Brazos Electric Power Cooperative, Inc.; City of Austin; El Paso Electric Co.; Gulf States Utilities Co.; Oklahoma Gas and Electric Co.; Plains Electric G&T Cooperative, Inc.; Public Service Co. of Colorado; Seattle Department of Lighting; Southern California Edison Co.; and Virginia Electric and Power Co.

The project is a key element in EPRI's effort to develop a viable electricity generating option. This test will give utility operating personnel first-hand experience with a complete solar-to-electricity generating system. The selected utility teams will provide technical assistance to the contractor, operate the experiment during part of the solar test phase, and participate in the assessment of the concept and the system.

EPRI researchers say the experiment is complementary to DOE's 10-MW Solar One Project under construction near Barstow, California, which is funded by DOE, Southern California Edison, and the Los Angeles Department of Water & Power.

Unlike the Barstow project, however, the Albuquerque experiment will test a solar-fossil hybrid system. When the sun is shining, its concentrated energy will heat air to 1500°F to turn a turbine and generate electricity. When the sun is not shining, the same turbine will run on a clean-burning liquid fossil fuel.

The EPRI-funded experiment will use air, rather than water, as the heat transfer fluid. This air-cooled central receiver technology has been under development by Boeing for EPRI since 1974. It offers simplified design and plant siting flexibility because water will be almost eliminated. The experiment is scheduled to begin by mid-1982 and power generated during the test may be fed into the test site's distribution grid. ■

H-Coal Pilot Plant Achieves Continuous Operation

The H-Coal pilot plant in Catlettsburg, Kentucky, has achieved a first by continuously handling high-sulfur Illinois coal for 45 days. The plant, which produces coal-derived liquid fuels, began operation in the spring of 1980 and has a coal capacity of 250 t/d.

"The achievement of sustained, long-duration operation at the H-Coal plant confirms the essential process features of the H-Coal technology. It is one of the leading liquefaction technologies that may be used for producing synthetic crude from coal," commented EPRI project manager Norman Stewart.

"The success of the long-duration tests confirms design scale-up from 3 t/d to 250–600 t/d," Stewart explained. "Engineering problems can now be studied from the base of long-duration test experience." Continuous operation had previously been prevented by pressure let-down valves, which were replaced by improved equipment earlier this year.

Hydrocarbon Research, Inc., which has been involved in the development of the H-Coal process since 1963, was in charge of engineering for the pilot plant. Ashland Synthetic Fuels and Badger Plants, Inc., handled plant construction. Ashland is operating the plant, with technical support and laboratory assistance from Hydrocarbon Research.

DOE is providing about 85% of the funding for the plant. Other participants are the Commonwealth of Kentucky, EPRI, Ashland, Conoco Coal Development Co., Mobil Oil Co., Standard Oil of Indiana, and Ruhrkohle (Federal Republic of Germany). EPRI has been involved in the project since 1974 and has a current commitment of about $12.5 million. ■

Coal Transportation Model Training Course

To facilitate transfer of EPRI R&D results to member utilities, the Supply Program of the Energy Analysis and Environment Division recently offered a training course to utility representatives on a transportation model, Transportation Network Model of Energy Supply Analysis, which was developed under RP1219-3. Held in EPRI's Washington Office May 6–8, the course provided an overview of the project and the use of its model. Edward G. Altouney, project manager, explained that the transportation model "provides the electric utility industry with powerful tools to assist them in forecasting the costs of coal transportation from the coal supply regions to the coal demand regions of the United States."

EPRI's contractor on the project, C.A.C.I., Inc.–Federal of Washington, D.C., conducted the course, presenting an explanation of the model, its network structures, and some specific applications. Other applications include determining the quantity trade-offs between transportation cost, shipper service, and energy use; evaluating the impact of transportation innovations, such as slurry pipelines (in which coal is mixed with water and piped across the country), truck-rail interconnected service, and increased truck size limits; comparing energy use, cost, and service results of various energy conservation options; and providing traffic-flow and energy-use data for environmental impact statements. The model can also measure the ability of a transportation system to deal with temporary or long-term reductions in service from strikes, bankruptcies, floods, or other disasters.

Five utilities sent representatives to the training course: Southern Company Services, Inc.; Houston Lighting & Power Co.; Metropolitan Edison Co.; Portland General Electric Co.; and Delmarva Power & Light Co. Staff from the Edison Electric Institute and its consultant, C. W. Fauth Co., also attended.

Through questionnaires distributed at the end of the first day, the utility representatives confirmed that this method of technology transfer is particularly effective, and all the participants were interested in attending similar courses. According to Altouney, the training course approach "more effectively transferred the results of this research project than relying solely on the publication of the final report." Some of the participants suggested that the course be placed on videotape, which would allow utilities to use this training course at their own convenience.

The project's final report will include a description of the computer model and an analysis of the capacity of existing and currently planned transportation networks to handle projected regional and nationwide coal movements from supply to demand regions. ■

CALENDAR

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

JULY

15–17
Workshop: Fabric Filter
Denver, Colorado
Contact: R. C. Carr (415) 855-2422

AUGUST

26–27
Workshop: Fossil Plant Heat Rate Improvement
Charlotte, North Carolina
Contact: A. F. Armor (415) 855-2961

SEPTEMBER

9–11
Workshop: Modeling of Cooling-Tower Plumes
Chicago, Illinois
Contact: John Bartz (415) 855-2851

17–18
Seminar: Compressed-Air Energy Storage (CAES)
Chicago, Illinois
Contact: Robert Schainker (415) 855-2549

17–18
Symposium: Underground Cable Thermal Backfill
Toronto, Ontario
Contact: T. Rodenbaugh (415) 855-2306
S. Boggs (416) 231-4111

21–25
Workshop: Zero Discharge
Steamboat Springs, Colorado
Contact: Roger Jorden (303) 824-4411
Winston Chow (415) 855-2868

30–October 2
Review and Workshop: 1981 Solar Program
St. Paul, Minnesota
Contact: E. A. DeMeo (415) 855-2159

R&D Status Report
ADVANCED POWER SYSTEMS DIVISION

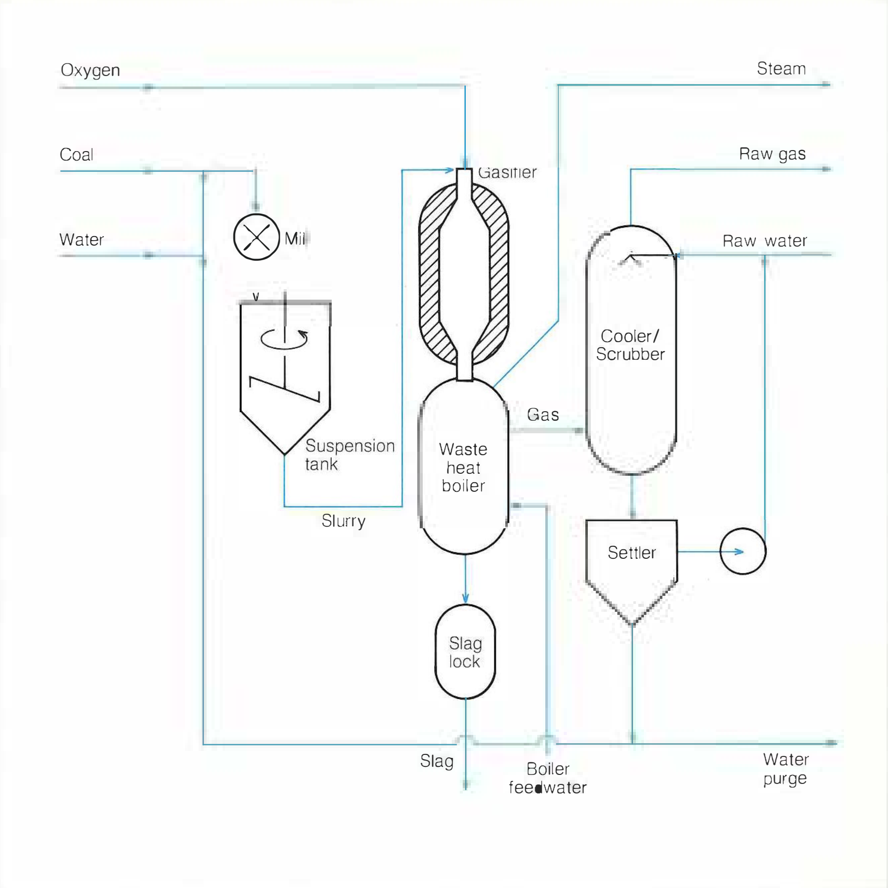
Dwain Spencer, Director

COAL GASIFICATION: RUHRKOHLE–RUHRCHEMIE'S ADAPTATION OF THE TEXACO PROCESS

The incentives for commercializing coal gasification–based power generation systems prompted EPRI to become a participant in the Cool Water demonstration project. Two of the challenges of Cool Water will be to scale up the Texaco coal gasification process to a commercial-size module of 1000 t/d and to integrate the gasification system with power generation equipment. In October and November 1980, EPRI conducted tests on the Ruhrkohle-Ruhrchemie 165-t/d Texaco gasifier at Oberhausen, Federal Republic of Germany (RP1799). The results of these tests, reported below, have created optimism that scale-up and system integration will be successful at Cool Water.

The rationale for EPRI's selection of the Texaco process as a strong candidate for utility use and the status of the Cool Water project were reviewed in the April 1981 issue of the *EPRI Journal* (p. 39). Tests of the 15-t/d gasifier at Texaco's Montebello, California, research laboratory (RP985-1) provided encouraging results on the process (*EPRI Journal*, October 1980, p. 37). However, the key technical issue of scale-up could not be addressed at Montebello. In question was the performance of a large unit at the design point, at turndown, and during transients; both conventional process data and environmental data were needed. Acquiring this performance data at an intermediate step between Montebello and Cool Water was the primary objective of the tests at the Oberhausen unit.

Figure 1 Ruhrkohle-Ruhrchemie gasification process development unit.



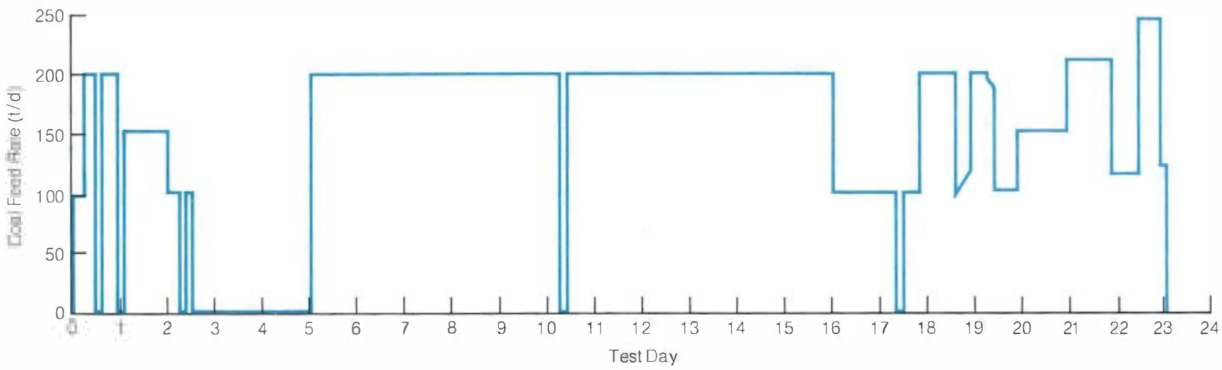
Plant design and test program

The Oberhausen process development unit was jointly funded by Ruhrkohle, Ruhrchemie, and the West German Federal Ministry of Research and Technology. Located in a large chemical complex of Ruhrchemie, the unit has logged over 7500 hours of operation since its startup in February 1978.

The unit sections evaluated during the EPRI test program were slurry preparation, gasification, heat recovery, particulate scrubbing, and water recycle. Figure 1 is a flow diagram showing the configuration of these sections in the Ruhrkohle-Ruhrchemie unit at Oberhausen during the EPRI test. After particulate scrubbing, the raw gas goes to a Sulfinol unit for H_2S, COS, and CO_2 removal, and from there it is routinely used as synthesis gas for chemical production or as boiler fuel. The steam from heat recovery is delivered to the plant steam system. The slag is normally marketed.

The EPRI test program consisted of a 6-day pretest, which was followed by a physi-

Figure 2 Main EPRI gasification test at Oberhausen. Instrument faults during the first few days of operation caused brief shutdowns and downtime for repair. Then, except for a brief shutdown caused by problems in the boiler house, the plant was operated steadily for 11 days to gather environmental data. The last week of operation (concluding in a controlled, scheduled shutdown on day 23) was spent conducting dynamic experiments and operating the gasifier under a variety of conditions to fully characterize its performance.



cal inspection, and a 20-day main test. Some 4400 t of as-received Illinois No. 6 coal was gasified during the runs. Illinois No. 6, a readily available high-sulfur coal, has been the basis for most of EPRI's comparative economic evaluations of gasification technologies. It was also used in EPRI-sponsored tests at Montebello and EPRI will test it at Cool Water (the Cool Water design coal is a lower-sulfur Utah coal).

In the 6-day pretest, operating parameters were explored. An inspection was then performed to determine if the American coal posed any hazard to the mechanical integrity of the plant. This inspection revealed that the operating conditions being used were too severe, and changes were implemented as necessary for the main test.

Figure 2 shows the coal feed rate to the gasifier during the main test. A faulty instrument caused brief shutdowns in the first 2.5 days; the plant demonstrated an ability to recover quickly from trip-outs on these occasions. After the instrument was repaired, environmental data were gathered for 11 days, using two different water system configurations. The remainder of the run was spent conducting dynamic experiments and operating the gasifier under a variety of conditions to fully characterize its performance.

Test results

Steady-State Performance Steady-state system performance was consistent and predictable. The gasification reactor was controlled well with the instrumentation in place during the EPRI runs, although some improvements have been identified and partially implemented. Performance was excellent at full throughput and was acceptable at turndown conditions. The results give cause for optimism about system scale-up to the Cool Water size.

Table 1 shows typical test results from Montebello and Oberhausen. Differences in performance can be attributed mostly to differences in coal heating value and slurry concentration. In a commercial plant most of the unconverted carbon could be separated from the slag and returned to the gasifier. A carbon recovery and recycle system was not in place at Oberhausen, so the efficiencies were proportionately lower than could be achieved commercially. The reported overall thermal efficiency considers

Table 1
EPRI TEST RESULTS ON THE TEXACO PROCESS

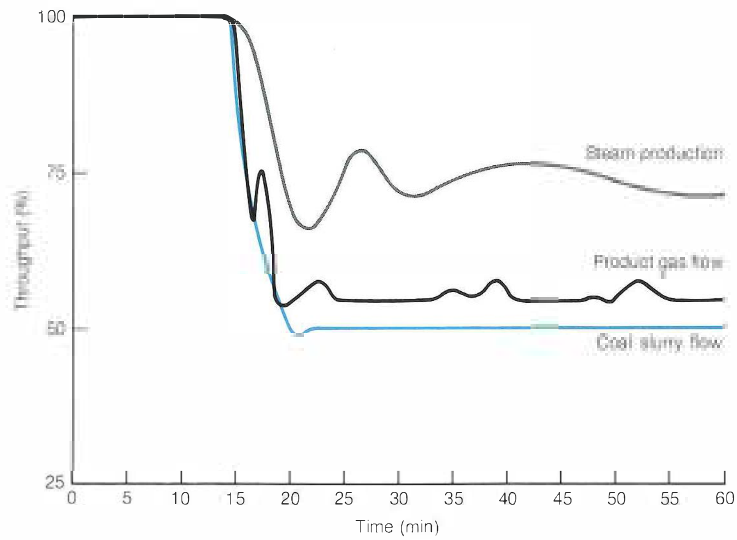
	Montebello	Oberhausen	
Coal feed rate (dry short ton/h)*	0.7	7	5
Coal heating value (Btu/lb dry coal)	11,600	12,400	12,400
Slurry concentration (wt% solids)	60	59	57
O_2/coal ratio (lb/lb dry coal)	0.93	0.93	1.03
Carbon conversion (%)	99	95	98
Cold gas efficiency (%)†	68	67	65
Overall thermal efficiency (%)	68	82	84
Raw gas composition (vol %)			
CO	42.2	41.2	39.8
H_2	34.4	36.5	35.1
CO_2	21.7	20.7	23.6
H_2S and COS	1.3	1.1	1.1
N_2	0.4	0.5	0.4

*Illinois No. 6 coal was used in all tests.
†Higher heating value of clean product gas/higher heating value of coal feed.

the cold gas efficiency plus the usable energy (steam) produced in the waste heat recovery system. Because the Montebello unit has no heat recovery system, its overall thermal efficiency is the same as the cold gas efficiency. At Oberhausen only high-temperature heat recovery was performed during the EPRI runs; intermediate-temperature heat recovery (to about 400°F; 204°C) would add approximately three percentage points to the thermal efficiencies achieved.

Dynamic Performance Many rapid rate changes were conducted on the Oberhausen reactor. Figure 3 illustrates a change from 100% to 50% throughput in 5 min. Oscillations in the product gas flow were caused by action of the plant's back-pressure control valve. Despite these oscillations, it is clear that the product gas flow rate instantaneously followed the gasifier feed rate. As expected, changes in the steam production rate lagged behind changes in the raw gas production rate. Also demonstrated was the sensitivity of the steam production rate to the oxygen/coal ratio. The observed fluctuations in this rate were due to manual trimming of the oxygen rate to hold the oxygen/coal ratio constant. This trimming was necessary because the oxygen flow rate is not automatically linked to the coal slurry flow rate at Oberhausen. All these results will be factored into the Cool Water control system design.

Figure 3 Gasifier dynamic response to a 50% reduction in coal slurry throughput in 5 min. The product gas flow follows changes in the gasifier feed rate instantaneously, while, as expected, the steam production rate lags slightly behind.



Equipment Durability All equipment was carefully inspected before and after the EPRI runs. Ultrasonic and X-ray measurements of metal thicknesses were made to augment careful visual inspections. Although all the results are not yet in, there appeared to be no excessive metal loss in any portion of the system. None of the unscheduled shutdowns during the test runs was due to hardware failure. The heat recovery unit performed satisfactorily; no excessive fouling or erosion-corrosion was evident.

Gasifier refractory evaluation was also an important aspect of the EPRI tests. Two different refractories lined most of the gasifier. Both performed satisfactorily under the modified operating conditions used during the main test. A lifetime of more than one year can be extrapolated for these refractories, which is commercially acceptable.

Environmental Tests Eleven days of operation were dedicated to environmental evaluation. This length of time was needed to allow the water system to come to steady state. Data were taken for two process water configurations. In the first, the entire settler underflow (Figure 1) was sent to a settling basin and the basin overflow was discharged. The overflow amounted to about 1.3 pound of water per pound of dry coal fed to the process. In the second configuration, much of the settler underflow was recycled to slurry preparation, which resulted in an aqueous discharge of only about 0.6 pound per pound of coal. The second configuration is more representative of a commercial configuration, especially in cases where makeup water is at a premium.

Samples of all effluent streams—slag, water, and product gas—were taken and are being analyzed for all priority pollutants. Trace element balances are being determined around the entire gasification system, and slag leaching studies are under way. The results to date and the gross properties of the effluent streams (e.g., dissolved solids in the aqueous effluent and particulate loading of the product gas) indicate that the Cool Water plant will be environmentally acceptable and will be able to meet all effluent requirements for which it was possible to test at Oberhausen.

Confirmation

EPRI's tests at the Oberhausen process development unit have confirmed the suitability of Ruhrkohle-Ruhrchemie's version of the Texaco coal gasification process for application to electric power generation. General process performance was as expected on the basis of the smaller-scale Montebello tests. The observed differences were relatively minor, and there is every reason to expect that scale-up to the Cool Water gasifier size will be successful. Dynamic behavior of the process was also generally as expected, and integration of the gasification system with the power generation equipment at Cool Water should be possible with modern controls. Preliminary results confirm that the Texaco process is environmentally acceptable. The mechanical integrity of all the process equipment was demonstrated. The performance of the gasifier refractory was particularly encouraging.

Analysis of the vast amount of Oberhausen data is continuing. The results to date have provided significant design input for the Cool Water project and have confirmed the appropriateness of EPRI's selection of the Texaco process for power generation application. *Project Manager: John McDaniel*

R&D Status Report
COAL COMBUSTION SYSTEMS DIVISION

Kurt Yeager, Director

NUCLEAR ANALYSIS OF COAL

In the next few months, two utilities will benefit from the application of the first on-line instrumentation for the continuous nuclear analysis of coal (CONAC). These analyzers represent the culmination of an R&D effort sponsored by EPRI; Science Applications, Inc.; and Kennedy Van Saun (a subsidiary of McNally-Pittsburg Manufacturing Corp.) and carried out by SAI and KVS. (Full background information on this instrumentation, called CONAC by EPRI and Nucoalyzers by SAI and KVS, is presented in the July-August 1980 EPRI Journal.*) In March the first of the instruments, a continuous sulfur analyzer, underwent acceptance testing at Detroit Edison Co.'s 3000-MW Monroe plant. A second instrument, a batch-sample sulfur analyzer, will be installed at the Tennessee Valley Authority's Paradise plant. A third instrument, a prototype that performs the equivalent of a complete element and ash analysis of coal on-line, is also scheduled for installation at TVA's Paradise plant later this year. The commissioning of these analyzers represents a significant advance in instrumentation for coal quality control.*

Coal tends to be highly variable in composition. This variability, stemming from the coal's origins 300 million years ago, is evident through the process stream from mine to boiler. Traditional methods of coal analysis involve collecting small samples from a large coal stream and measuring coal constituents by laboratory techniques. It often takes a day or more for the results of such an analysis to become available. By this time the coal is through the process stream and in many cases already burned; thus no process control is possible. In addition, the sampling systems themselves can introduce bias into the analysis. A mechanical device that has to sift through several thousand tons of coal to produce a test sample of a few grams entails considerable uncertainty.

The advantage of CONAC over traditional techniques is that it enables accurate, real-time analysis of a significant fraction of a coal stream. The present design has a capacity of 50 t/h and will measure the amount of most elements in the coal, along with moisture content and heating value, in less than 30 minutes. Important parameters, such as sulfur and ash content and heating value, can be accurately analyzed or calculated in 10 minutes or less. By applying these rapid results to the control of coal handling, utilities will be able to use coal resources more efficiently and meet increasingly stringent environmental requirements more reliably and economically.

CONAC instrumentation is based on a well-established technique called prompt neutron activation analysis (PNAA). This technique has found acceptance in a wide variety of industrial applications where more traditional techniques have proved impossible. CONAC uses a small specimen of radioactive californium (Cf-252) to bombard a coal stream with neutrons. As the energetic neutrons collide with the atomic nuclei of the coal constituents, they lose energy to these nuclei, especially to those of hydrogen. When the neutrons have lost sufficient energy in this way, there is a probability that they will be captured by the nuclei instead of bouncing off them. The magnitude of this probability depends primarily on the physical characteristics of the individual elements. It does not depend critically on either the chemical environment of the nuclei or on the size distribution of the coal sample.

When a neutron is captured by an atomic nucleus, gamma rays are emitted that have a frequency characteristic of the element involved. CONAC uses radiation detectors to count the number of gamma rays at each characteristic frequency. The number for each is proportional to the abundance of the element associated with that frequency. This technique, under development for the last four years, has been successfully used in a laboratory prototype CONAC to analyze 200-lb samples of a wide variety of U.S. coals. These results are reference data against which the accuracy of the first generation of on-line instruments will be measured.

Coal-blending application

Control of coal blending is the first problem to which the on-line nuclear analyzer is being applied. At its Monroe plant, Detroit Edison has elected to meet strict state SO_2 emission requirements by blending more-expensive low-sulfur eastern coal with less-expensive high-sulfur eastern coal. Although coal blending avoids the high initial costs of alternative emission control techniques, such as stack gas scrubbing, its long-term cumulative costs are high because low-sulfur coal is increasingly expensive. These costs can be minimized by using only as much of the low-sulfur coal as necessary to meet the emission standards. However, since the variation in the sulfur content of both the high- and low-sulfur coals is large, there is no single optimal blending ratio. Instead, this ratio is a dynamic parameter that can change within minutes.

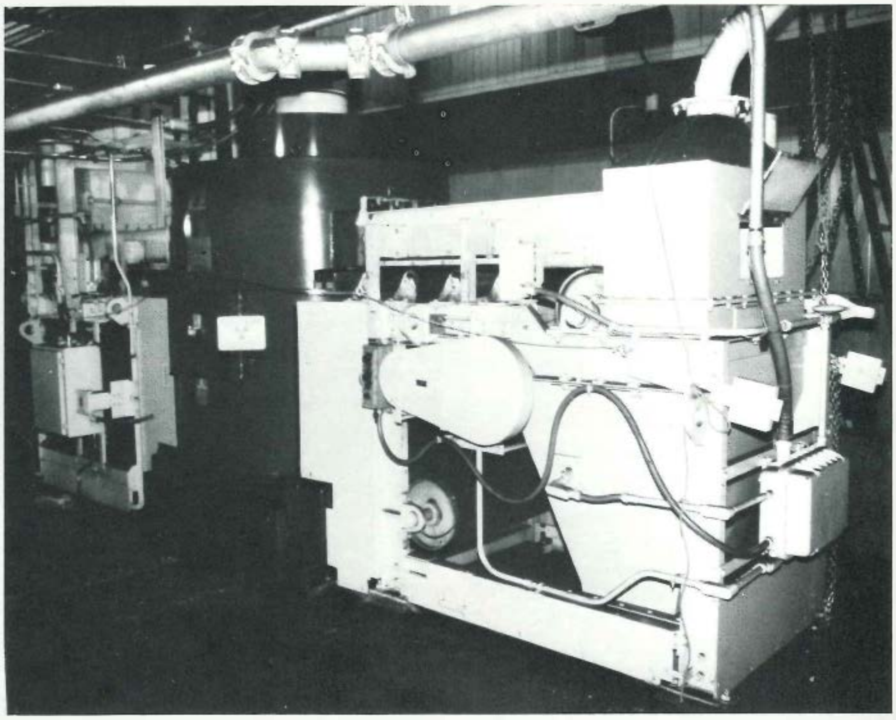
Knowing the range of each coal's sulfur content allows a blending ratio to be chosen that will ensure that emission levels are not exceeded, but this means uses more of the costly low-sulfur coal than is necessary. To predict what savings would result from optimizing the blending ratio on the basis of feedback from an on-line sulfur analyzer, Detroit Edison used data on plant operating parameters and the sulfur content and heating value ranges of its targeted coals in a mathematical model. The model predicted that an annual savings in fuel costs of over $10 million could be realized by using optimized blending ratios rather than a fixed blending ratio.

To meet this need, SAI and KVS built a simplified CONAC instrument called a sulfur meter (Figure 1). This instrument, which has been running on-line at Monroe since last March, gives the necessary feedback signal on sulfur content to enable the continual optimization of the coal blending ratio. Eventually it will control the speed of two rotary plows that will continuously load the main plant feed belt from piles of high- and low-sulfur coal. (This system is scheduled to come on-line in 1982.)

Currently at Monroe, the coals are loaded by stacker reclaimers and blended according to a fixed ratio per fill (about 4 hours). Coal entering the plant is sampled by an automatic sampler, and the rejects of the secondary sampler (about 3 t/h) are analzed by the sulfur meter. Results on the sulfur content of the coal in each fill are then used by plant operations and fuel supply personnel to set subsequent fill blending ratios to meet 24-hour emission requirements.

Figure 2 shows output from the sulfur meter at the Monroe plant over a 12-hour period. During this time coals of various sulfur levels were fed into the plant silos. For the first 5 hours, 100% low-sulfur coal and blends of high- and low-sulfur coals were used. For most of the next 6 hours, 100% high-sulfur coal was analyzed. At about the sixth hour, the plant coal feed was stopped

Figure 1 One of the first sulfur meters to see service is this unit designed and built by Science Applications, Inc., and Kennedy Van Saun. It is now being tested at the Monroe plant of Detroit Edison Co., where coals of different cost and sulfur content are blended for economy and compliance with environmental emissions standards.



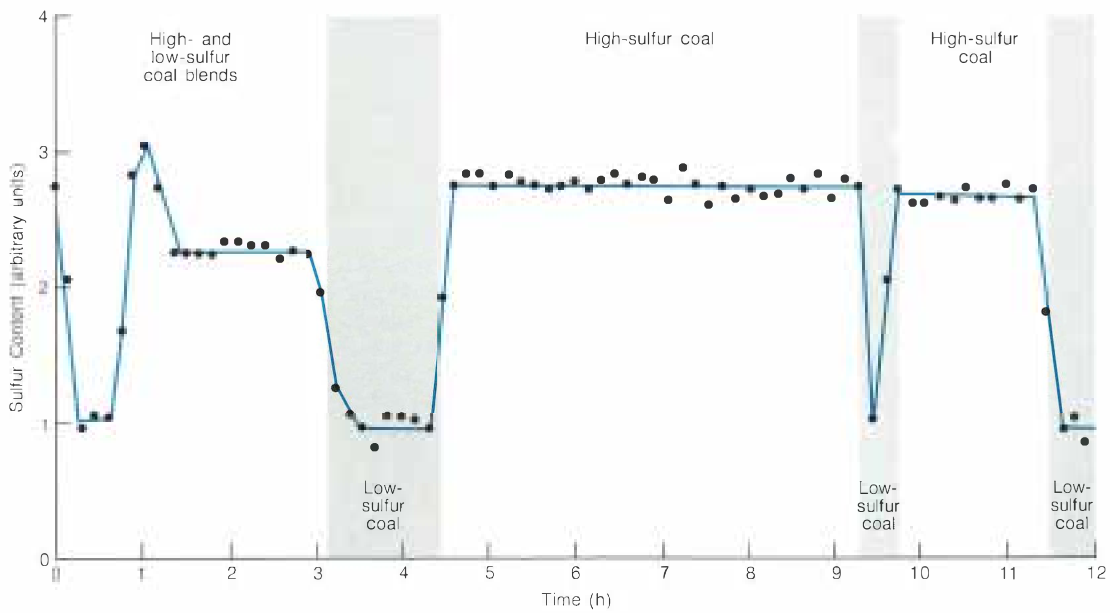


Figure 2 On-line sulfur meter readings from Detroit Edison's Monroe plant for high- and low-sulfur coal feeds.

and the sulfur meter measured the same coal for approximately an hour; the small deviations in the measured sulfur content during this time indicate the precision of the instrument ($\pm$0.04 wt% sulfur). After the stationary coal measurements were made, the coal feed was restarted. Subsequent deviations in the measured values indicate variations in the sulfur content of the high-sulfur coal.

An extensive comparison is planned between the sulfur meter results and results obtained from stop-belt sample analysis and from standard ASTM analysis of samples collected in the automatic sampler. These tests will lay the groundwork for eventual acceptance and approval of PNAA instrumentation as an ASTM method.

Coal preparation application

The next two CONAC instruments—a batch-sample sulfur analyzer and a total elemental analyzer—will be installed at TVA's Paradise coal preparation and power plant. The Paradise power plant, which consists of two 704-MW units and one 1150-MW unit, is required to meet an SO_2 emission standard of 3.1 lb/10^6 Btu (3-hour average). The strategy for complying with this limitation calls for coal with a sulfur content equivalent to 5.7 lb/10^6 Btu of SO_2 to be used in all three units. Units 1 and 2, the smaller units, also have scrubbers to further reduce SO_2 emissions to 0.9 lb/10^6 Btu. To produce coal of the required quality, a new coal preparation plant was begun in 1978.

The preparation plant, constructed by Roberts & Schaefer Co., will wash up to 2000 t/h of 3-in $\times$ 0 coal from western Kentucky Nos. 9, 11, and 12 seams for use by the Paradise generating units. It consists of four independent modules that use heavy-media separation for 3-in $\times$ 28 mesh coal and hydrocyclones in combination with froth flotation for coal below 28 mesh. Clean coal from all four modules is conveyed to another building for temporary storage and sampling.

Both the batch-sample analyzer, known as a rapid sulfur meter (RSM), and the total element analyzer, known as CONAC, will be located in the storage-sampler building. The RSM instrument will be used to monitor the sulfur content of the clean coal to ensure that an acceptable sulfur level is maintained at maximum Btu recovery. With information from the continuous sulfur readout, plant operators will be able to adjust the specific gravity of the heavy media to avoid both excessive coal loss from overwashing and possible penalties if SO_2 limitations are exceeded because of underwashing.

Possible savings are difficult to predict without actual data on RSM field performance or on washing performance. However, an example based on a 1% increase in Btu recovery will serve to illustrate the potential of advanced instrumentation and control techniques in coal preparation plants. The Paradise plant must wash approximately 7.8 million tons of coal (10,500 Btu/lb, 95% Btu recovery) to produce the equivalent heating value of the 7.4 million tons of unwashed coal required by the plant each year (80% load factor). An increase in Btu recovery from 95 to 96% would therefore result in savings equivalent to approximately 81,000 t/yr of the original 10,500-Btu/lb coal. Although coal costs vary widely, depending on individual contracts, transportation costs, and other factors, savings of \$1.6 million to \$3.6 million would result for coal in the \$20–\$45/t range.

CONAC, to be installed at Paradise later this year under joint EPRI, SAI, and TVA sponsorship, will provide element analysis for carbon, hydrogen, sulfur, nitrogen, silicon, iron, aluminum, calcium, chlorine, sodium, and potassium; additional sensors will provide moisture and coal mass flow rate information. Derived quantities, such as heating value, total ash content, and fouling and slagging indexes, will also be displayed.

SAI, KVS, TVA, and EPRI are jointly sponsoring extensive testing of the CONAC instrument to demonstrate the usefulness of complete on-line element analysis both in process control and in boiler performance evaluation (Figure 3). This program will include a careful comparison between ASTM and CONAC results for coal obtained by the sampling system and also by stop-belt sampling. Ash composition will be correlated with the performance of the heavy-media and froth flotation operations to provide insight into the detailed dynamics of the cleaning process. The CONAC results will be used to study how power plant performance—including boiler heat output, fouling and slagging episodes, and scrubber performance—is affected by coal composition. This work should demonstrate the potential benefits of tailoring plant operating conditions to the exact character of the feed coal.

Coal consumption both for electricity generation and in other applications has been steadily increasing over the last decade, and several estimates forecast accelerated consumption—from 0.68 $\times$ 10^9 t/yr in 1979 to 2 $\times$ 10^9 t/yr in 2000. The need for faster and more accurate coal analysis is overwhelming. The 1980s will see widespread application of CONAC instrumentation in all sections of the coal industry. For the first time, utilities will be able to continuously monitor what they are buying and burning. Performance data on the instruments going on-line this year should give a clear indication of CONAC's potential benefits. *Project Manager: Owen Tassicker*

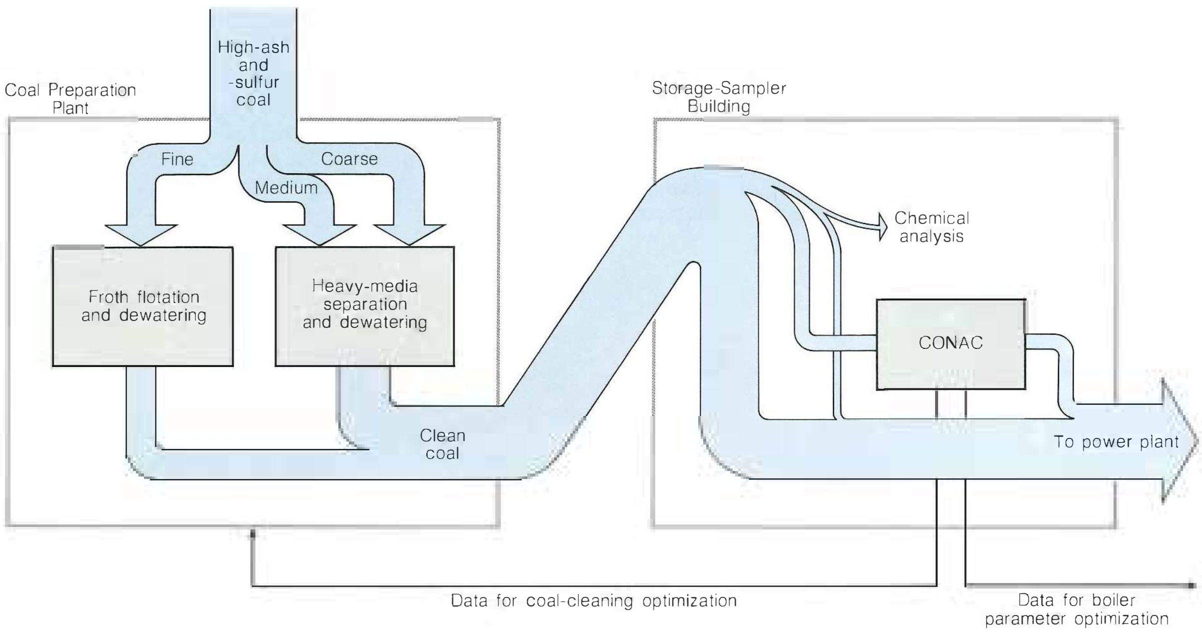
COAL-OIL MIXTURES AND COAL-WATER SLURRIES

The tightening supply of oil and gas, their increasing cost, and federal directives to eliminate their use as fuels for electricity generation have prompted utility interest in the conversion of oil-fired power plants to coal. Under RP1455 and RP1895, EPRI is investigating two relatively near-term alternative fuels that hold promise for facilitating this conversion: coal-oil mixtures (COM) and coal-water slurries (CWS).

In the past coal was the principal utility fuel. Then, primarily in the 1960s, large sections of the industry switched to oil or gas. Many coal-design plants have been or are being reconverted to coal, but for various reasons some cannot be; for example, land for coal storage and handling facilities may no longer be available. Of the units originally designed to burn oil, a minority (about 20%) were built with coal-firing potential. However, the conversion of these coal-capable units requires major capital expenditures. In cases involving boilers designed for oil only, modification for coal firing requires an outage as long as two years. The remaining service life of many units is insufficient to make such major modifications economical.

COM and CWS may lower the cost of conversion at such plants by enabling the continued use of the in-place oil transport and storage infrastructure. COM technology has been under development for some time, and utility demonstrations have been conducted. The advantage of these mixtures over pulverized coal is that they can be transported, stored, and handled without extensive changes to existing oil-firing facilities. CWS, although having a lower heating value than COM, has the further advantage of eliminating the use of oil altogether. If a very low ash coal is used in the slurry, derating of the unit may be minimized. This approach is compatible with coal-cleaning processes under development, which produce a water-wet slurry of fine coal. Use of the coal in this wet state would eliminate costs and handling problems that would otherwise be entailed. However, CWS development lags behind the COM state of the art by about two years.

Figure 3 Continuous nuclear analysis of coal. A 20-t/h stream of clean coal will be fed into CONAC at TVA's Paradise plant. The element analysis produced by CONAC will be used to monitor the coal-cleaning process and to optimize it by adjusting the foaming agents or the specific gravity of the heavy media. CONAC data related to fouling and slagging, heating value, and moisture content will be used to adjust boiler parameters.



Coal-oil mixtures

The usefulness of this fuel has been explored for almost 100 years. Recent development activity started in 1976, stimulated mostly by DOE initiatives. Since then, fuel preparation processes have been developed to produce pilot plant quantities of mixtures of about 50 wt% coal and 50 wt% oil, plus small amounts of slurry stabilizers (CS-1695). Several utilities and industrial boiler owners are seriously evaluating the use of COM. Boiler combustion and performance tests were initiated at the Saginaw plant of General Motors Corp. (RP527) and have grown in scale and sophistication. (Results are presented in DOE report FE2267-2.) Demonstration tests are under way at New England Power Service Co.'s 80-MW (e) Salem Harbor Unit 1 (with DOE support) and at Florida Power & Light Co.'s 400 MW (e) Sanford Unit 4. Also, Florida Power Corp. has announced plans to fire COM at its 120-MW (e) Bartow Unit 1.

It has become apparent that the technical and economic factors to be weighed by potential COM users are complex and highly site-specific. In 1979 EPRI initiated a study to provide utilities with guidelines for evaluating the effect of COM firing on representative boilers and for predicting the cost of COM prepared by typical processes (RP1455-2). This study has been conducted by a team that is headed by Arco Petroleum Products Co. and includes Bechtel Corp. and Combustion Engineering, Inc.

COM Conversion Guidelines In defining the scope of the EPRI study, it was assumed that utility boilers designed to fire pulverized coal but converted to fire oil could be reconverted to coal or, in cases where this was not a reasonable option, could be evaluated for COM conversion on the basis of the experience gained at New England Power Service Co.'s Salem Harbor project. It was also assumed that for utility boilers designed to fire gas only, conversion to COM would be too expensive to be a viable option. The study therefore concentrated on units designed to fire oil, specifically units with high furnace-plan-area heat release rates.

Six large utility boilers were selected for detailed case studies. These units were considered representative of the potential COM market in terms of capacity (370–850 MW [e]), age (over 20 years of remaining service life), configuration (close-coupled screen, close-coupled arch, box, or conventional), and outlet steam pressure (12.4–16.5 MPa; 1800–2400 psi). Five of the units were designed to fire oil only, and one has a triple fuel capability (coal, oil, or gas). The study focused on sites along the Atlantic coast because boiler sales records showed that to be the principal location of conversion candidates, and also because there are several attractive potential sites for COM production plants in that region.

Recent steam generator performance data from units firing oil were used to calibrate existing computer programs for predicting furnace and convection pass performance. On the basis of experience in firing eastern coals in units with plan-area heat release rates of over 2×10^6 Btu/ft^2, assumptions were made about the rate of furnace wall slagging when firing COM and the effectiveness of deslaggers. Furnace performance predictions were then made for COM firing under the expected slagging conditions. The furnace load limit was determined by holding the outlet temperature below the point at which the convection pass would be either overheated or severely fouled with semimolten ash. In some cases, because of the high gas velocities in units designed for oil firing, ash particle erosion also limits load capability.

The predicted derating when using a COM consisting of 50% No. 6 oil and 50% Pocahontas coal (with an ash-softening temperature of 2160°F; 1182°C) ranges from 50 to 60% for the five oil-design units studied. A COM that is 50% Kittaning coal (with an ash-softening temperature of 2700°F; 1482°C) is expected to result in a derating of 20–30% in close-coupled arch units, 30–40% in close-coupled screen units, and 40–60% in box-type units.

Modifications required for conversion from oil to COM firing include the following.

- Replacement of furnace bottom and ash hoppers for 50° slopes
- Addition of furnace deslaggers
- Installation of new burner tips (or new burners)
- Addition of ash removal equipment
- Addition of fly ash collection equipment

The results of this study clearly show that the extent of derating and the cost of modification are highly dependent on coal quality, unit characteristics, and site-specific factors. The data and analysis from this project will provide utilities with guidelines for COM conversion.

COM Production Costs The other objective of the study was to predict the cost of producing COM in a central preparation plant and delivering the fuel by barge to potential users. Initially, several likely sites for such a preparation plant were identified: Boston, Port Reading (New Jersey), Baltimore-Norfolk, and Jacksonville (Florida). A transportation cost analysis was then performed, and Baltimore-Norfolk was chosen as the study site because of its proximity to coal reserves and its central market position. On the basis of the potential market, transportation factors, and the size of processing equipment now commercially available, the plant size was set at 90,000 bbl/d of a COM product of 50% coal and 50% No. 6 oil. This size is equivalent to 3 GW (e) of power generation.

Several alternative manufacturing methods were considered for the processing facility. The one chosen for a more detailed economic evaluation involves dry grinding of the coal, followed by mixing with No. 6 oil. This process is the furthest developed commercially, but it is likely that future designs will shift to wet grinding. An analysis of feed costs (coal and oil) has indicated that low-ash, low-sulfur cleaned coal can potentially produce an economically attractive COM. To further evaluate this possibility, the use of oil agglomeration in conjunction with COM manufacture is being studied.

The final report for the study, to be published this fall, will include an analysis of the manufacturing costs, as well as a sensitivity study for all the costs associated with COM manufacture. Because prices of delivered coal and especially oil are so volatile, nomographs will be included to permit a rapid evaluation of COM cost for any raw materials cost.

Coal-water slurries

Highly concentrated slurries of finely ground coal in water represent another option for the conversion of oil-design utility boilers (and a few coal-design units) from oil firing to coal firing. As with COM, these slurries could be used without major modifications to fuel transportation, storage, and handling facilities. In addition to direct firing in utility and industrial boilers, highly loaded CWS are candidate fuels for pressurized fluidized-bed combustion and coal gasification systems.

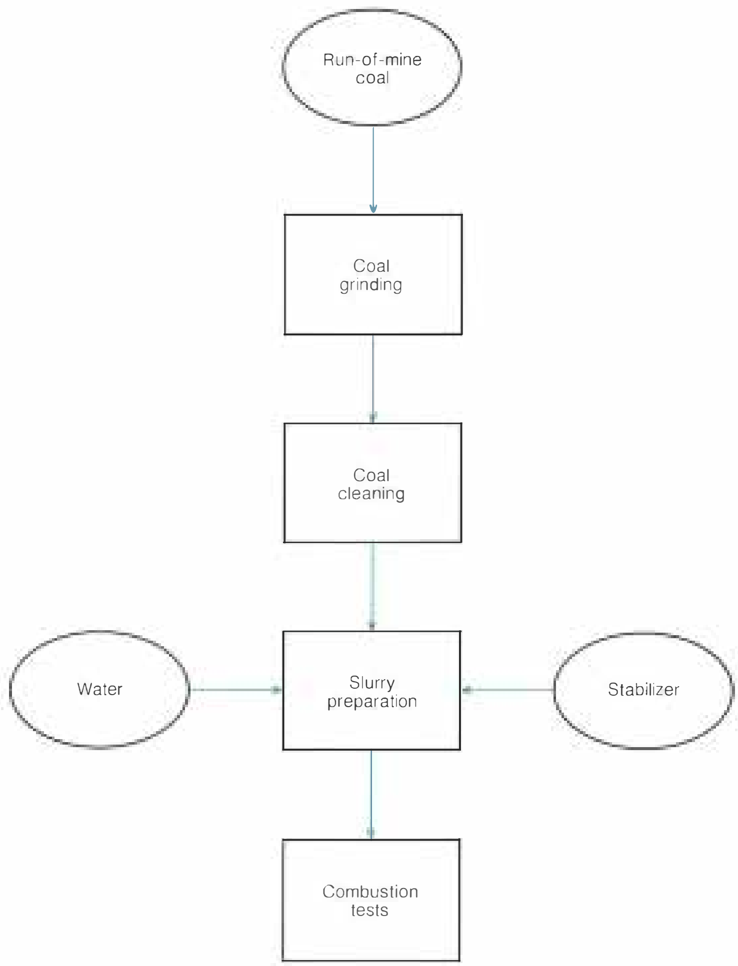


Figure 4 Preparation of coal-water slurries for testing in oil- and coal-design boilers. With this configuration, up to 80% of ash and pyritic sulfur can be removed before slurry preparation.

The technology for preparing pumpable, stable slurries consisting of 70 to 75% coal in 25 to 30% water (and typically containing less than 1% of a stabilizing additive) is under development by a number of organizations. Various coal feedstocks, coal treatment processes, grinding methods, and stabilizing processes are being studied. Slurries have been prepared in quantities of a few tons, and limited combustion tests have been performed in small furnaces. Development projects are under way to scale up slurry preparation processes and to demonstrate stable combustion in boilers.

Under RP1895 a pilot plant quantity (25 bbl) of a slurry consisting of 68% coal and 32% water was prepared by Atlantic Research Corp.; the coal used was cleaned at Pennsylvania Electric Co.'s coal-cleaning facility in Homer City, Pennsylvania. The slurry was then burned in a 5 $\times$ 10^6 Btu/h furnace at Babcock & Wilcox Co. The short test was successful in showing stable combustion at that scale. EPRI is planning projects to establish critical slurry properties, to identify required power plant system modifications (e.g., to burners, pumps, instrumentation, and emission controls), to assess benefits, and to demonstrate CWS performance in a utility boiler.

Table 1
TYPICAL COAL AND CWS CHARACTERISTICS

	Bituminous Coal*	Subbituminous Coal†	CWS
Moisture (%)	6	31	30
Sulfur (%)	3	0.55	1
Ash (%)	12	5	3
Gross heating value (Btu/lb)	11,910	8320	9800
Efficiency loss due to water evaporation (%)	1	4	3

*Williamson County, Illinois (ASTM Class II, Group 4).
†Campbell County, Wyoming (ASTM Class III, Group 3).

CWS Preparation A general process flow scheme for slurry preparation is shown in Figure 4. The mined coal is ground and cleaned to reduce the ash content by 50–80% (depending on the coal type and the efficiency of the cleaning process). Judging from the limited COM experience, it seems desirable to reduce the ash content to less than 5% to minimize derating. Up to 80% of the pyritic sulfur can be removed during the cleaning process if the coal is first completely pulverized. Carbon recovery rates should exceed 90%.

The ability to prepare practical slurries depends not only on the properties of the selected coal, such as grindability and surface chemistry, but also on attaining the right particle sizes and size distribution. In addition, the proper chemical additive must be selected to provide good flow and storage stability characteristics.

The size distribution of the pulverized-coal particles must be such that the interstitial spaces between the largest particles are filled with smaller particles. The grinding process must therefore be carefully controlled to achieve a good particle-size fit. Grinding methods based on existing practices in the ceramics, paint, ore processing, and aerospace industries have been used.

Grinding can be done in a single step, or a coarse grind and a fine grind can be prepared separately and then blended. The single-step grinding process has been used to prepare practical slurries that are 65–75 wt% coal; the average particle diameter is about 50 μm. When the two-step process is used, the average particle diameter of the coarse fraction (about 70 wt% of the coal) is typically 100 μm and that of the fine fraction (30% of the coal) is about 15 μm.

A typical CWS contains a small amount (less than 1%) of a stabilizing additive to prevent solids settling and also to provide the desired flow properties for a given application. Samples of slurry supplied to EPRI by a number of potential producers are fluid and feel silky but tend to be thixotropic.

The largest batch of CWS reported to date weighed 25 tons, and pilot plant production is slated to start at a number of sites in 1981.

CWS Combustion A number of questions about CWS combustion remain to be answered. These include whether the slurries will burn in utility boilers with a stable flame, what efficiency loss will result from evaporation of the water, and what capacity loss will be experienced.

The indications are that CWS will burn. Flame stability problems in the past have been attributed not so much to high water levels in the slurry as to variability of slurry composition and feed rates. A CWS that is 70% coal has a heating value between those of typical bituminous and subbituminous coals (Table 1).

Tests in small burners (1 $\times$ 10^6 Btu/h, 5 $\times$ 10^6 Btu/h, and 30 $\times$ 10^6 Btu/h) have produced encouraging results. The 1 $\times$ 10^6 Btu/h tests were conducted at Atlantic Research Corp. in a furnace consisting of a 9-ft-long (2.7-m) water-jacketed tube with an inner diameter of 20 in (508 mm). The initial 3–4 ft (0.9–1.2 m) of the tube were refractory-lined. Secondary air was preheated to 600°F (316°C), and the furnace was preheated with oil. When CWS was introduced, a stable flame formed; combustion remained stable when the oil feed was shut off.

Twelve tons of a 70% coal slurry were fired in Babcock & Wilcox Co.'s 5 $\times$ 10^6 Btu/h test rig. Again the combustion air was preheated to 600°F, and again stable combustion was attained. A 30 $\times$ 10^6 Btu/h burner was used in Sweden by Carbogel for open-air and flame tunnel tests with ton quantities of 70% coal slurries. The findings indicate stable combustion even in open air.

The efficiency loss from water evaporation can be calculated, and it is expected to be less than 4%. Oil-design boilers firing CWS will also require derating. Projects to be initiated this year will analyze the extent of this derating.

Much work remains to be done to fully assess the potential of CWS as an oil replacement fuel. The utility industry and EPRI are planning to conduct projects to advance the state of the art of CWS technology. To identify critical slurry properties and to establish working specifications for CWS firing, this year EPRI will seek competitive bids for a combustion test program with slurries made by various processes and from different coal stocks. Another project will be initiated to demonstrate combustion in a larger boiler and to demonstrate and develop the state of the art of pumps, burners, valves, on-line instrumentation, and other equipment. Further plans call for a multiyear utility-scale demonstration to be started in 1982. *Project Manager: Rolf Manfred*

R&D Status Report
ELECTRICAL SYSTEMS DIVISION

John J. Dougherty, Director

DISTRIBUTION

Concentric neutral cable corrosion

The corrosion of copper concentric neutral wires surrounding underground residential distribution (URD) cables is a problem of increasing concern to utilities. With over 200,000 mi (321,800 km) of URD cable now installed, and an additional 100,000 mi (160,900 km) to be installed within the next decade, the incidence of copper corrosion can be expected to increase. The potential consequences of an open neutral are unreliable operation of protective devices, unbalanced voltage, overvoltage conditions, and hazards to repair crews.

During 1981 EPRI will complete a three-year project to determine the cathodic protection criteria and guidelines necessary for proper control of corrosion in direct-buried copper concentric neutral cables (RP1049). Because of national interest in this project and the requests of many utilities, Volumes 1 and 2 of the three-volume final report will be published in the summer of 1981. These first two volumes include major conclusions of the project and results of field tests in California, Oklahoma, and North Carolina. The cathodic protection guidelines will be included in Volume 3 of the report, which is planned for publication in late 1981.

Of particular note in the report are details of the electrochemical, chemical, bacteriological, and sieve analyses of soils from various test locations. Also, some causes of the neutral corrosion are included, along with protection criteria.

According to test data analyses performed by the contractor, Pacific Gas and Electric Co., a leading cause of corrosion of the concentric neutral wires is use of backfills that are coarser than "sand with silt," as classified by the American Society for Testing and Materials. Imported backfills are usually sandy, much coarser, and therefore more corrosive to concentric neutral wires than most native soils. Backfills with a clay content higher than 20% generally provide a uniform environment with low corrosivity. Hence, the plow-in method for installing concentric neutral cables (which involves only native soils) usually provides a more uniform and less corrosive environment than trenching, especially when a coarse imported backfill is used to fill the trench.

The prevailing mechanism for severe localized corrosion is the formation of differential concentration cells. These cells are formed when certain metals are in contact with an aerated soil at one point and an oxygen-deficient soil at another location; this condition frequently exists under coarse backfill or in unsealed plastic conduits.

Another contributing source is tin alloy coatings, especially when the coatings are more noble than the exposed bare copper.

Both high-density ac leakage current and dc currents can cause corrosion. High-density ac leakage occurs when faults in secondary cables attempt to find a return path to ground and the neutral of a nearby primary cable becomes the path. Stray dc currents emanate from electrified railroads, from transit systems, and (most often) from cathodic protection systems installed on other underground structures.

Soils with high concentrations of hydrogen sulfide, peat, or cinders can be a chemical cause of corrosion.

Concentric neutral wires often are in contact (through grounding systems) with less noble metals, such as steel or galvanized steel conduits, ground rods, water pipes, or reinforcing bars in concrete. These contacts provide some degree of cathodic protection to the copper neutral wires. The level of cathodic protection can be measured with a high-resistance dc millivoltmeter connected between the neutral wire and a reference electrode placed on the earth's surface above the cable. However, this measurement is not always reliable, especially if a very high resistivity material was used as a backfill. In such cases, a very small cathodic protection current can produce misleading high negative (protected) potentials when the reference electrode is placed on the earth's surface and positive (corroding) readings when the electrode is placed close to the neutral wires.

A plot of voltage measurements between the cable and a reference electrode placed directly above the cable can be made; however, even if taken at close intervals, this plot is neither reliable nor practical for predicting locations where corrosion is most severe or where galvanic anodes should be installed. In areas without cathodic protection on concentric neutral cables, maximum corrosion can often be found in moist soils where the neutral-to-soil potentials are more negative than the rest of the cable. Another method that can be used for locating corrosion is to monitor the resistance of the neutral between transformers or splice boxes and compare these measurements with the calculated value. Any increase in resistance will indicate a corroded neutral.

Preliminary results from experimental cathodic protection systems indicate that in a large majority of locations, cathodic protection will control corrosion of continuous copper neutral wires, if applied properly. In most locations, including those with ac leakage (up to 50 mA/ft of cable), less than 100 mA of dc current per 1000 feet of cable will be required to achieve cathodic protection. Cathodic protection can be achieved using 17-, 20-, or 32-lb (7.7, 9.1, or 14.5-kg) magnesium anodes, prepackaged in backfill. Also, constant-current rectifiers with high-silicon cast iron or platinized columbium anodes can be used. The cathodic protection rectifiers should have an output of 100 to 250 mA, and the distance between systems may be 300–1000 ft (92–305 m). Anodes should be installed at least 10 ft (3 m) deep and 10 feet from any metallic underground structures. Detailed installation recommendations will be included in Volume 3 of the final report. *Project Manager: T. J. Kendrew*

POWER SYSTEM PLANNING AND OPERATIONS

Component outage analysis methods

Power system reliability studies help determine the need for new facilities. Statistics on the behavior of individual components are the most important data in calculating system reliability. However, today's complex questions regarding system reliability require improved methods to analyze outage data; these methods should recognize both engineering and statistical aspects of data analysis.

A 20-month project (RP1468) with Westinghouse Electric Corp., initiated in February 1979, was one of a group of projects aimed at evaluating the reliability of bulk power delivery system components, such as generating units, transmission lines, and transformers. The analysis methods developed in this project will help in understanding the failure causes and failure modes of various types of components. The emphasis was on methods of forecasting outage statistics for those components used in evaluating system reliability.

The project provided a perspective on how the statistical methods could be used to improve outage data analysis and illustrated the application of certain statistical methods. Also identified were areas that limit the data analysis, such as inexperience in analyzing many kinds of outages on diverse types of equipment, and incompatibilities between failure models and outage data.

In identifying better methods for predicting outage statistics and measuring the confidence in these statistics, this project has laid sound foundation for understanding outage processes and analyzing the resultant data. A detailed discussion of statistical methods relevant to outage data analysis is presented, including ways to apply the methods using actual utility system data. The final report on this project will be available by mid-1981. *Project Manager: Neal J. Balu*

Human factors in control centers

Operators in hundreds of U.S. electric utility power dispatch centers are responsible for delivering power to customers economically and reliably. Although the record of these operators has been impressive, on occasion operators are misled by the information presented to them. Time lost in trying to trace missing information or in determining whether information is relevant can result in uneconomic operation, damage to equipment, or even customer interruption.

Each member of the dispatching team receives power system information visually and audibly and implements decisions by pushing a button or issuing an order. Over the last few years, technological changes in the dispatch center environment have increased the amount of information automatically presented to the dispatching team. In addition, the need for personnel to man supervisory control and data acquisition installations has increased the number of operators geographically dispersed at subarea control stations who can help diagnose system problems.

An EPRI project was initiated to study the dispatch control center environment, in which the power system dispatching team is expected to perform with a minimum number of errors (RP1354). The project has three phases.

- Survey the design practices used in dispatch centers
- Define the needs for and uses of power system information
- Identify improved methods and techniques for presenting information

During the first phase, particular attention was given to design factors that affect dispatcher efficiency and those that tend to cause errors. Room lighting, noise levels, work station layouts, concurrent demands for action, viewing angles, and viewing distances represent the types of factors evaluated. Human-engineering criteria and analytic techniques that had been proved in the design of aircraft and manned spacecraft were applied to the information collected.

An interim report on the findings of a human factors survey of 13 contemporary control centers will be available from EPRI's Research Report Center at the end of July 1981. This report provides design guidelines that will help satisfy human-engineering needs, improve the control center environment, and minimize possibilities for human error at dispatch control centers. The results of this first phase will also be discussed by a panel at the 1981 IEEE Summer Power Meeting in Portland, Oregon.

In the second phase, currently under way, researchers will examine the information requirements associated with various modes of power system operation. Reasons for presenting certain information to dispatch team members during each mode of power system operation will be investigated in depth. Before digital computers were used to support dispatch functions, much information based on measured parameters was unprocessed. Computers have been and will be employed in many centers to detect and give warning of erroneous or incomplete data. Researchers will ascertain whether more or less data processing would benefit the dispatcher. An action-oriented point of view will be taken during this analysis; for example, what action is the dispatcher expected to take when a particular set of data is presented? Do the kind of information and the way it is presented elicit the correct dispatcher response, especially during emergency and restorative operations? Information should neither overwhelm the dispatcher nor be insufficient for decision making.

The third phase, to be started later this year, is planned to improve methods of presenting information to the dispatch team through better use of existing hardware and software, the addition of new hardware and/or software, or a combination of these. For example, in some nonutility operating environments, prerecorded voice-alarm messages have been effective; it is possible that such systems would be effective in the power system dispatch center. Cordless headsets, new wallboard display techniques, voice-actuated software, and television projectors are other possibilities to be evaluated. *Project Manager: Charles J. Frank*

TRANSMISSION SUBSTATIONS

HVDC converter transformers

When the need for high-voltage dc converter transformers arose, the industry based its design on the inherent characteristics of cellulose insulation and transformer oil, as used in standard large power transformers. However, these insulation materials react differently to dc voltages than to ac voltages. Ac voltages distribute inversely proportional to their dielectric constants, whereas dc voltages distribute directly proportional to their resistivities. The dc resistivity of insulation material is in most cases affected by the temperature, electrical stress, and length of time the material is exposed to the dc stress.

Figure 1 shows the results of resistivity measurements taken on oil-impregnated cellulosic insulation and on transformer oil. As can be seen, the resistivity values of oil and of cellulosic insulation at a temperature of 20°C differ by several orders of magnitude; as the temperature increases, the difference becomes smaller. This difference in resistivity leads to an unequal stress distribution between oil and the solid insulation material. In fact, the stress distribution is exactly opposite from that observed under ac conditions. Since dc and ac electrical stresses both exist in dc converter transformers, the design engineer has to consider both voltage distributions, and increased overall electrical clearances will result.

In cooperative efforts, EHV Weidmann, Inc., in Vermont and General Electric Co. are working to improve the dielectric system for converter transformers. General Electric is also studying the effect of direct current bias on the magnetic circuit of the transformer.

In a 33-month EPRI project, EHV Weidmann Industries, Inc., and H. Weidmann Ltd. of Switzerland are investigating the dc characteristics of various natural and synthetic fibers and chemical additives (RP1424-1). The goal of the project is to use these materials to lower the resistivity of the solid insulation material, especially in the lower temperature range, so that its resistivity approaches that of the transformer oil. Should this be accomplished, it would have a significant effect on the economics of insulation design, including additional savings in the size and weight of a dc converter transformer. Physical as well as chemical modifications of the fibers are being studied, and a series of additives is also under test. Once a suitable insulation material has been developed, the improved material will be tested to verify its electrical, mechanical, and chemical performance under dc converter transformer operating conditions.

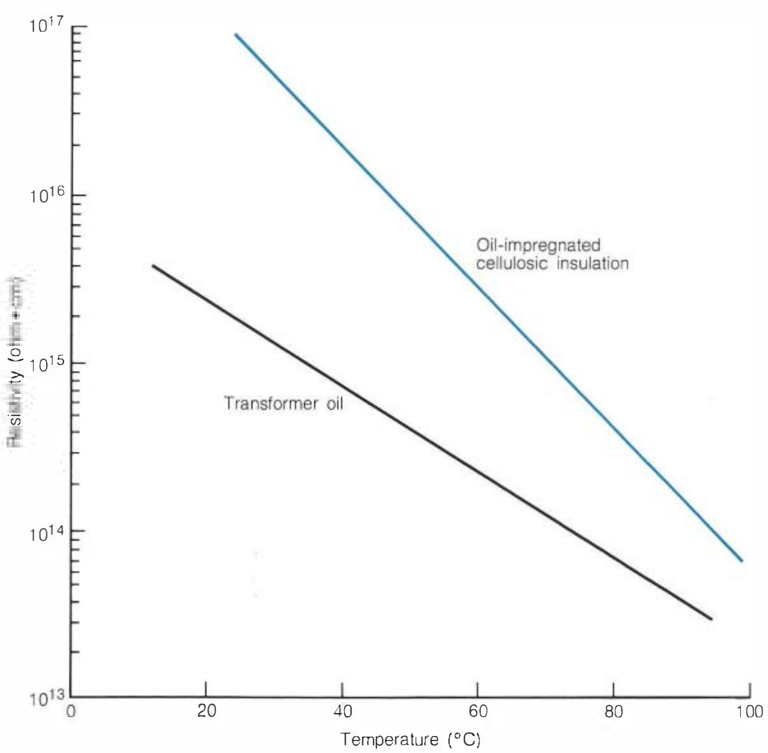
Under a separate contract, General Electric has identified several promising development opportunities in the area of transformers and smoothing reactors for application to HVDC power transmission systems (RP1424-2). One near-term opportunity involves improvement in coordination between dielectric requirements for system operation, standard dielectric tests, and the intrinsic dielectric capabilities of the insulation systems employed in converter transformers and reactors. This project will undertake fundamental studies leading to recommendations that will facilitate the efficient design of insulating systems for HVDC converter transformers and smoothing reactors. Specifically, the study will seek a basic understanding of failure mechanisms and of the effects of increased volume or area on the projection of these data to larger apparatus. The goals of the project are twofold: to ensure high reliability in HVDC apparatus and to enable the design of smaller, more efficient, lower-cost equipment.

At present, fundamental work is well under way to examine breakdowns through oil insulation (strikes), and designs have been completed for the larger model testing. Models to investigate streamer development parallel to oil solid insulation (creep) have been designed and built and are now being tested.

General Electric is also studying the effect of direct current bias on the magnetic circuit of a converter transformer (RP1424-3). The project is aimed toward developing an adequate understanding of the effects of direct current excitation of transformers on reactive power flow, accelerated material deterioration, and increased sound levels; this understanding will be applied in an assessment of the possible deleterious effects of direct current in power transformers.

The two-year effort includes an analytic development phase and an experimental verification phase. In the analytic phase, techniques will be developed to study the distribution of magnetic flux in the transformer while the core is operating partially in saturation because of the flow of direct

Figure 1 Variation with temperature of the resistivities of transformer oil and oil-impregnated cellulosic insulation. The difference in resistivities (of several orders of magnitude at low temperatures) leads to an unequal stress distribution between oil and solid insulation, which ultimately forces design engineers to increase overall electrical clearances.



currents in the windings. These techniques do not now exist, and it is important for a transformer user to know what deleterious effects he may experience from direct currents. The techniques developed will be used to study the principal core types that are most susceptible to direct currents, and generalized methods for dealing with these problems will be developed. The techniques developed will be confirmed in an experimental verification phase in which a fully instrumented model transformer will be tested. *Project Manager: E. T. Norton*

Analysis of transmission line transients

In a development effort sponsored by EPRI, Westinghouse Electric Corp. has built two systems for recording transmission line transients (RP751). These systems have been installed at two Florida Power & Light Co. substations and have been operating since July 1980. Analysis of the recorded data is being pursued as a part of the Westinghouse contract and also under separate contracts with the University of Pittsburgh (RP1422-1) and Rensselaer Polytechnic Institute (RP1422-2). As described in an earlier status report (*EPRI Journal,* May 1980, p. 47), Westinghouse will evaluate the transients from a dielectric design engineer's point of view, and UP and RPI will look at the data from a relay designer's viewpoint.

Each recording system is connected both to the transmission circuits (for direct measurement of currents and voltages through high-fidelity transducers) and to the low-voltage side of conventional current and coupling capacitor voltage transformers (CCVTs). This arrangement allows for the assessment of effects on protective relaying devices—for example, the effect of bandwidth limitations of conventional relaying transformers.

The differences between actual transmission line voltage and the output response of a typical CCVT can be seen in Figure 2. At first glance, the traces do not seem to have much in common. A closer scrutiny will reveal that the first two or three cycles of the transient are fairly well matched, both with respect to peak voltages and for the points in time at which the voltages are zero. After the first few cycles, the zero points remain relatively well matched, but amplitude error increases significantly.

Information of this type will allow typical voltage- and current-measuring devices to be modeled and the effects of those devices on the performance of protective relaying systems to be assessed. This is of particular importance for the development of fast-operating protective relays. Such relays may interpret a distorted voltage or current wave form as a fault even if the distortion is of short duration. The distortions could also have the effect of slowing down the operation of the relay when there is a fault. The transmission line transients captured on the recorders may bring a better understanding of the effects of these instrument transformer errors, allowing the industry to produce better protective relays in the future.

The protective relaying field is only one of many areas where the recorded data can potentially be used; nearly everyone involved in the design of transmission lines and substations could benefit from the collected data. It is expected that the data collection period will end in late 1981 and that at least the initial data analysis will be completed in early 1982. *Project Manager: Stig Nilsson*

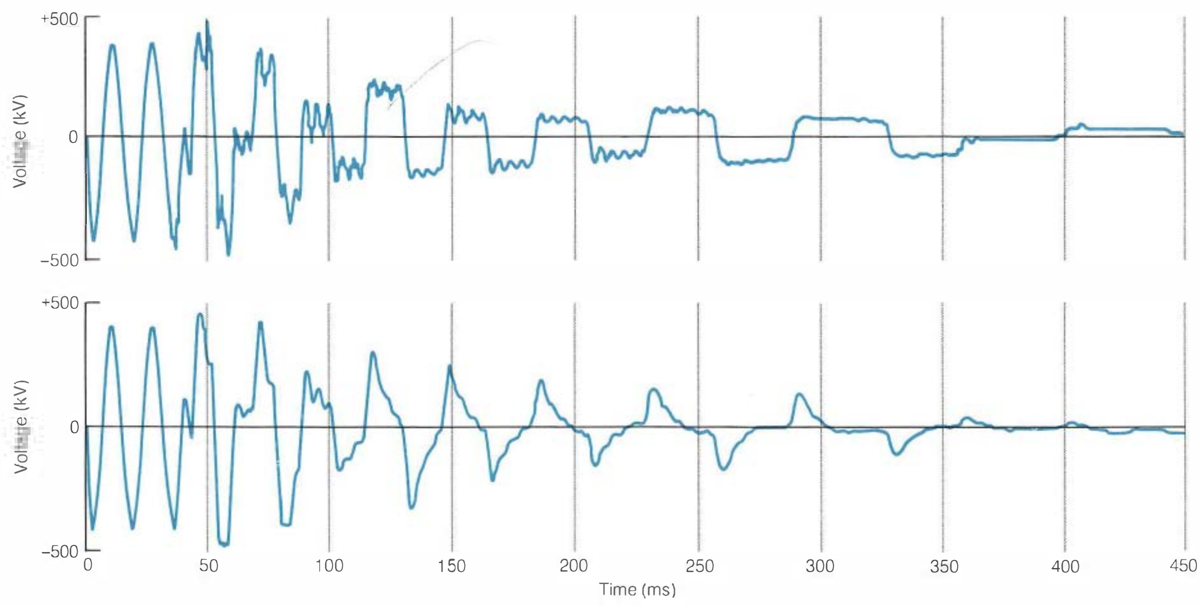


Figure 2 The measurement of currents and voltages on high-voltage transmission lines requires compromises between the need for accuracy and the desire for low cost. A coupling capacitor voltage transformer (lower trace) can reproduce relatively well the first few cycles of a complex wave form (upper trace) resulting from deenergization of a transformer-terminated 500-kV line. The transients were captured by special recorders that EPRI had installed at Florida Power & Light Co.

OVERHEAD TRANSMISSION

Wood pole design

Wood poles have traditionally been a popular choice for supporting utility transmission lines. However, the substantial variability in strength and stiffness properties of wood poles has necessitated the incorporation of large nominal safety factors in designs to ensure structural reliability. The purpose of EPRI-sponsored research in this area is to discourage ultraconservative designs for wood transmission line structures by defining ways to achieve a consistent, well-defined level of safety and reliability (RP1352). The contractor, Research Institute of Colorado, has concluded the first phase of this effort, and the results are expected to offer substantial economic benefits to utilities using single wood pole transmission line construction on their systems. The final report is scheduled to be available shortly.

Safety factors are built into each technical aspect, or layer, of a design, but not always with the same precision. For example, values for material strength may be set quite low; assumptions or simplifications in structural analysis often lead to added safety factors; values for loads such as wind and ice may be selected on the basis of the worst weather conditions ever experienced in that area; a factor for overall margin of safety is traditionally applied to ensure that any unforeseen problems are covered in the design. Safety factors for each of these design layers must be refined before a consistent and realistic level of safety can be maintained.

The contractor first made an in-depth study of all the full-scale pole tests that have been run in the United States and Canada. This was done with the assistance of pole suppliers, the U.S. Forest Products Laboratory, the University of Wisconsin, and the Canadian Western Wood Forest Products Laboratory. This search resulted in the identification of 3002 pole tests. Of these, the great majority involved distribution-size poles (Figure 3). Only 15 of the tests were performed on transmission-size poles longer than 55 ft (17 m), and all these were of the same species. With such a limited sample available on which to base the material strength and stiffness values required in formulating design criteria, it is clear that additional tests of the larger transmission-size poles will be required before a rational safety factor can be established.

Assumptions and simplifications in design procedures can result in underdesigned structures. Such is the case when the effects of vertical load on a deflected structure ($P - \Delta$ effect) are not considered (Figure 4). This $P - \Delta$ effect can result in substantial secondary moments on the pole, especially on tall single-pole transmission structures. As part of this project, an easy-to-use design/analysis computer program was developed to incorporate $P - \Delta$ effects into the design. This program, POLEDA-80, is available in both CDC and IBM versions and will perform the design/analysis computations for single-pole, unguyed, wood and tubular steel transmission line towers. POLEDA-80 is now available through EPRI's Electric Power Software Center. The use of more-exacting design tools of this type can reduce the need for larger safety factors in design.

Meteorologic loads, such as wind and ice, constitute the primary design loads that must be considered for transmission lines. Addition of unnecessarily high safety factors in compensating for these loads can have pronounced effects on the overall economics of the line; on the other hand, failure to recognize areas where higher loading conditions exist can produce catastrophic results. Wind and ice loading conditions can be extremely variable in their likelihood of occurrence in different areas.

Historically, the meteorologic data used in establishing local design wind loads have been supplied by only 129 weather stations distributed across the United States; some of these stations are located several hundred miles apart. Thus, an individual utility requires more wind and ice data to arrive at the safety factor appropriate for its transmission line design. Improved, probability-based design methods are now being developed that should provide an easy means for incorporating these new data. In fact, these methods allow information on both design loads and material properties to be easily added, thus integrating all safety factors into one rational design approach. POLEDA-80 is configured to make use of this concept after it is fully developed.

Assessment of the feasibility of using probability-based procedures for the design of transmission lines was undertaken as a specific task on this project. Emphasis was placed on developing an improved design

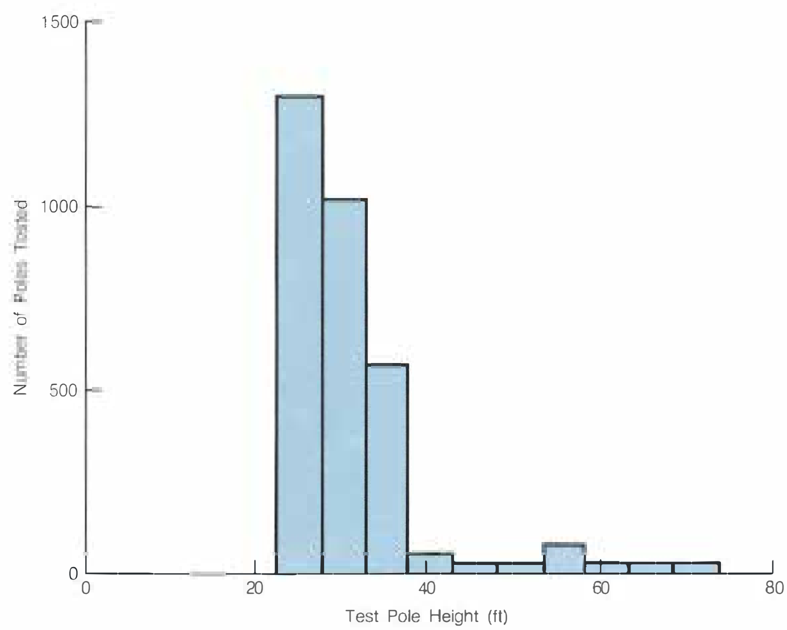
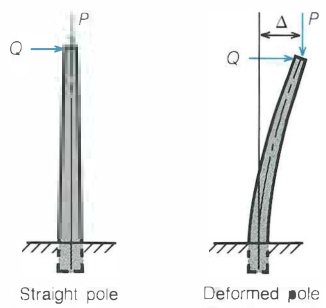


Figure 3 Range of heights for all utility poles known to have been laboratory tested for physical strength in the United States. Clearly the vast majority were distribution-size poles (40 ft and below), leaving a pressing need for data on poles of transmission size.

Figure 4 When a pole is deflected by wind force Q, the vertical load P further stresses the pole; this $P - \Delta$ effect increases rapidly with pole deflection and is more severe for tall poles than for short poles.



procedure that would avoid any additional effort on the part of the utility engineer or designer. As a first step, an easy-to-use, probability-based procedure was successfully developed for the design of unguyed, single-pole transmission lines. The design method can also be expanded to include more complex structures, as well as structures made of other materials.

This improved design methodology, as well as the results of the rest of this project, will be presented in detail in the final report, as well as at a series of regional seminars to be held in early 1982. *Project Manager: Phillip Landers*

Composite insulator for HVDC transmission

New dielectric materials are replacing porcelain and glass for overhead line insulators in many applications. One of the more popular designs, the composite insulator, uses a fiberglass rod for mechanical and electrical strength and flexible skirts made of organic materials for improved flashover performance.

The composite insulator appears to be especially attractive for use on HVDC lines, as insulators on a dc transmission line are subject to more severe contamination and do not benefit from the arc-extinguishing effect of the voltage zero on an ac line.

Two primary questions arise in considering the use of composite insulators on dc lines: whether the organic materials that make up a composite insulator will be adversely affected by dc voltage stress and what design will best cope with the more severe operating conditions imposed by HVDC. A recently completed project, cofunded by EPRI and Sediver, Inc., has provided answers to these questions, and prototypes of a composite insulator designed for HVDC applications are being manufactured (RP1206-1). Performance tests will begin this summer. A final report, available in late summer of this year, will detail the following major tasks performed in the project.

- A study of the organic materials used in a conventional ac composite insulator and the behavior of these materials under dc voltage stress
- A study of the contamination performance of various shed designs and an explanation of the ranking process used to determine an optimal design
- An evaluation of the reduction in the total cost of a transmission line that could be achieved by using a shorter insulator. (The newly designed composite insulator may permit a 30% reduction of the string length, as compared with conventional ceramic suspension insulators.)

The prototype insulators being manufactured as a part of this project will be field-tested under HVDC conditions on the test rack at the Sylmar converter station of the Los Angeles Department of Water & Power; the prototypes will also undergo artificial contamination testing in the fog chamber at Project UHV. Test results will be available in mid-1982. *Project Manager: John Dunlap*

R&D Status Report
ENERGY ANALYSIS AND ENVIRONMENT DIVISION

René Malès, Director

RATE DESIGN STUDY: CUSTOMER RESPONSE AND LOAD RESEARCH

The Electric Utility Rate Design Study, now in its sixth year of load management research, has published more than 80 reports on various technical aspects of assessing time-of-use (TOU) rates and direct load controls. Undertaken in response to a request by the National Association of Regulatory Utility Commissioners to examine ways of controlling peak demand growth and shifting use from peak to off-peak periods, the study is a nationwide research effort sponsored by EPRI, the Edison Electric Institute, the American Public Power Association, and the National Rural Electric Cooperative Association. The study's second phase (1978–1981) is organized into six major topics: customer response (or elasticity), costing and rate design, load research, equipment for load management, customer acceptance and understanding, and cost-benefit analysis. Research in each area will be summarized in a topic paper. This report discusses completed work on customer response (Topic Paper 1) and load research (Topic Paper 3).

Topic Paper 1: Customer response to TOU rates

Methodology Five steps are involved in predicting customer response to TOU rates (Figure 1). The first step entails the specification of a model structure for analyzing the relationships between patterns of electricity use and such use-determining factors as electricity prices, size and type of appliance stock, and level of economic activity. This step is typically based on inputs from economic theory, prior empirical research, and information from physical and sociodemographic studies. Price elasticities (dimensionless functions derivable from the model structure) are often used to summarize customer response to rate structure changes.

The second step involves the compilation of a data base on customer loads and use-determining factors. Data are typically drawn from primary sources (surveys and experiments) as well as from secondary sources (public and private records). The third step involves the selection of estimation techniques for determining customer response and the derivation of concepts for quantifying the uncertainty in model estimation.

Inputs from the preceding three steps are combined in the fourth step, and the estimation techniques are applied to the model and data base. In the fifth step, TOU rate structures are combined with the estimated model to generate predictions of customer response. These predictions are usually obtained through the estimated elasticities and are subject to qualification by the estimated measures of uncertainty.

Price elasticity measures can thus be used to predict the impacts of alternative rate structures on customer loads. By combining the predicted load impacts with rate structure information, it is also possible to predict the impacts on customer bills.

Empirical Results Topic Paper 1 (RDS No. 84) reviews results from several analyses of TOU rate programs. Because of differences in the scope of the studies and the type of data collected, it is difficult to derive many general conclusions from this body of research. Findings common to most of the studies are summarized below.

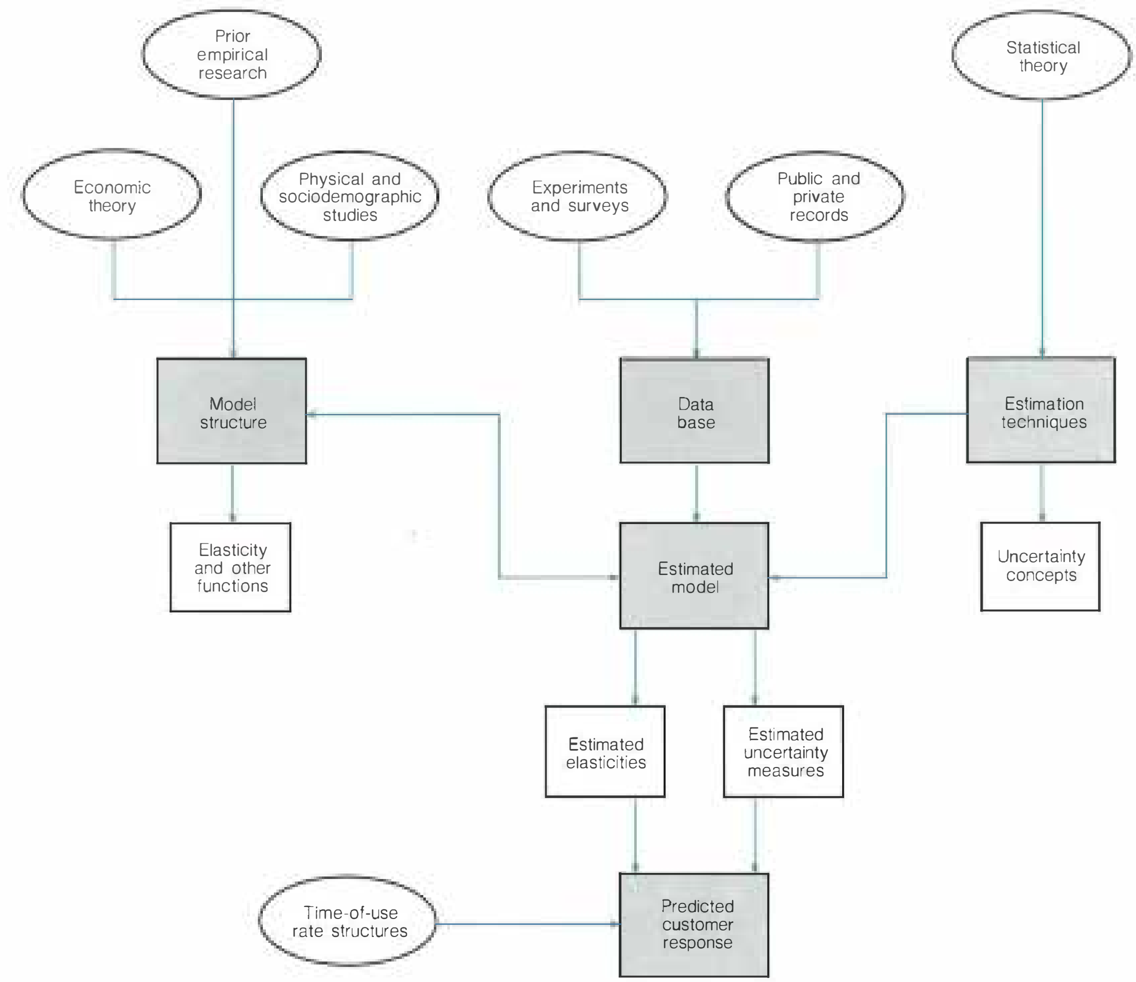
Results from seven TOU pricing experiments conducted by DOE indicate that the peak period energy consumption of residential customers tends to decline in response to TOU rates; analytic estimates of the size of the reductions range from 0 to 38%. The greater the differential between peak and off-peak rates and the smaller the length of the peak period, the greater the reductions tend to be. TOU rates apparently induce load reductions in all pricing periods and result in lower total energy use. Responses on the average weekday do not seem to differ from those on the day of the system peak.

The estimated price elasticity of peak period energy consumption ranges from 0 to −0.42. It seems to increase (in absolute terms) with increases in the ratio of peak to off-peak rates, level of total energy use, and ownership of discretionary appliances (e.g., swimming pool pumps and air conditioners) and to decrease with increases in the length of the peak period. The estimated off-peak price elasticity falls in a similar range (0 to −0.45).

Little evidence is currently available on the response of residential peak demand to TOU rates. However, for utility service areas with considerable diversity in residential loads, it is plausible to expect that results on peak period energy consumption will provide a good indication of peak demand response.

Results on the response of industrial and commercial customers to mandatory TOU pricing programs indicate that TOU rates usually induce reductions in both peak period energy consumption and peak demand. For data from one midwestern and three California utilities, estimated reductions in peak consumption range from 0.8 to 9.7%. The corresponding reductions in peak demand range from 3.2 to 10%. The level of response is related to the differential between on-peak and off-peak rates. The ob-

Figure 1 Methodology for predicting customer response to time-of-use rates.



served responses do not appear to be sensitive to the length of the peak period, but in some cases they are influenced by whether the weekday is an average day or the day of the system peak.

Response patterns differ substantially by industry. The more responsive industries include cement, steel, paper, and chemicals. This finding is consistent with the expectation that industries in which electricity costs make up a relatively large share of production costs, or which have a technological process that permits storage of intermediate products and rescheduling of end uses without interruptions in production, will be more responsive to TOU rates. Within a given industry, the larger facilities show a greater response.

Industrial facilities seem to be more responsive in periods when capacity utilization is slack, and facilities with access to cogenerated electricity appear more able to reduce use of purchased electricity during peak periods.

Price elasticities of energy consumption by time of use have been developed for a sample of 64 northern California firms in seven industrial and six commercial product classifications. The own-price elasticity for peak period consumption ranges from -0.06 to -0.23.

Because customer response measures are inferred through statistical techniques, they are characterized by some uncertainty. The degree of this uncertainty depends on the magnitude of error in each of the five stages of elasticity estimation. It is recommended that the several sources of uncertainty typically associated with a given set of elasticity estimates be identified, and an attempt made to assess their combined quantitative significance. Estimated price elasticity measures should be qualified with this uncertainty information before they are used to predict the impact of TOU rates.

If elasticities are to be transferred from one service area to another, an additional source of uncertainty arises: inter–service area variability in such characteristics as climate, customer mix, rate levels, pricing periods, and fuel availability. These characteristics can be expected to influence or condition elasticities; thus, in cases involving elasticity transfer, their role must also be assessed.

Topic Paper 3: Issues in load research

Load research involves the probabilistic analysis of load pattern data drawn from a sample of customers to make inferences about the load patterns of a larger number of customers, such as the relevant customer class. Topic Paper 3 (RDS No. 86) presents a review of load research issues and addresses three key questions: Why should a utility conduct load research? How can a utility develop load research data? Can load research data be transferred from one utility to another? The general conclusions of this review are summarized below.

Load research data provide an important input to three major utility planning areas: cost of service studies for ratemaking, evaluation of load management programs, and load forecasting. The Public Utility Regulatory Policies Act (PURPA) of 1978 requires utilities to file information on the first two areas. Load research data are an important part of this documentation.

Many utilities have research programs that served adequately in the past. Few of these programs, however, are able to fully satisfy either the growing internal need for data or the legal requirements of state and federal regulations. The extent of the need is indicated by the fact that Section 133 of PURPA alone requires far more load data from many utilities than they have previously collected.

Load research efforts typically have three phases: experimental design, data collection, and data analysis. Experimental design involves selecting which loads and other variables to measure, sampling techniques, and which customers to equip with recording devices. These decisions are key to successful load research because they set a limit on the statistical quality of results. It is in this phase that a trade-off must be made between the cost of the research and the cost of not having adequate data. To maximize the analytic usefulness of the experiment, it is necessary to collect data not only on end-use and aggregate loads, but also on such load-determining factors as economic, climatic, and demographic conditions.

Data collection, the second research phase, has most commonly been accomplished with magnetic tape recorders, but more reliable systems based on electronic memories are now being tested. The third phase involves the editing, verification, storage, retrieval, and analysis of the collected data, usually by a large-scale computer. It is important that analytic requirements be considered before data collection, not after. The needs of each potential user—the rate designer, load management analyst, load forecaster, or regulatory liaison—must be identified early in the research process to determine which analyses will be requested and, therefore, which data and format are most desirable. Although some utilities have developed their own computer programs for data analysis, commercial programming packages are now available.

Because load research is expensive and time-consuming, utilities may want to borrow data from other utilities. Some types of load data may justifiably be transferred from one utility to another. However, little is known about the validity of such transfer, and the application of borrowed data carries much uncertainty. Further research is necessary to specify the conditions under which borrowed data can be used and to quantify the uncertainty such transfer creates.

The Rate Design Study's review of load research suggests that utilities should expect to devote substantial funding ($500,000 a year or more) if they implement a full load research program. To ensure an efficient program, the needs of all departments involved in rate design, load management evaluation, and load forecasting must be considered in the experimental design. It will probably be necessary to collect economic, climatic, and demographic data, as well as load data. The review suggests that continuing improvement in communication among load research professionals will help make load research more cost-effective. *Executive Director: René Malès; Project Manager: Ahmad Faruqui*

PLUME MODEL VALIDATION

In the EPRI plume model validation project (RP1616), data are being collected on the transport, diffusion, chemical transformation, and ground level concentrations of pollutants emitted from fossil fuel power plants. The data are then used to validate existing plume models, following rigorous validation procedures and statistical methods. In addition, the models are subjected to scientific validation to learn how they can be improved by further development. This multifaceted effort is described in EPRI EA-917-SY.

Objectives and procedures

The first objective of the project is to provide rigorous and statistically defensible evaluations of the precision with which a variety of plume models predict pollutant concentrations. The ability of the models to predict the cumulative frequency distribution of ground level concentrations, particularly the extreme values (maxima), is emphasized, but predictions of concentration patterns and location relative to the source are also tested. The second objective of the project is to establish the scientific validity of the models and to provide guidelines for future model development.

The models are tested for the terrain and meteorologic conditions to which they might be applied. Three classes of terrain have been specified for these studies: flat plains, moderately complex or rolling hills, and mountainous landscapes. The meteorologic conditions tested range from stably stratified atmospheres to those characterized by strong convective instability. When these rigorous validations have been completed, selected models will also be validated against partial data sets from other sources (described in EA-1159) to evaluate model transferability to other, similar sites.

The facilities employed for field measurement include a network of 28 fixed and two mobile SO_2 monitors, 200 SF_6 tracer sampling stations, a 100-m central meteorologic tower, two acoustic Doppler satellite radars, a T-sonde ascent system, two aircraft, and two ground-based mobile lidar units. Stack emission rates are monitored routinely, and meteorologic data are obtained from the National Weather Service on a continuous basis. All data are stored as either 5-min or 1-h averages.

Formal operational validation procedures have been established (EA-1638), and a battery of statistical methods is available for various validation purposes (EA-1673-SY). Because the scientific validation procedures require diagnostic evaluation of the various modules that make up operational plume models, they are less formally structured.

To date, field measurements have been made during the spring and summer seasons at Commonwealth Edison Co.'s Kincaid power plant in central Illinois. Reliable data from these measurements have been used to validate four Gaussian plume models commonly employed for regulatory and operational purposes. The results of this work are summarized here and presented in detail in EA-1788.

Observed plume behavior

The observed maximum ground level SO_2 concentration tends to be independent of the SO_2 emission rate. A threefold change in this emission rate (from 4 to 11 kg/s) produced a nearly constant maximum ground level concentration of 500 $\mu g/m^3$ for the 30 highest SO_2 concentrations observed at Kincaid. More detailed analysis of these and more data are necessary, but results to date suggest that the maximum ground level SO_2 concentration tends to be independent of plant load or burn rate when a single tall stack is employed.

The maximum ground level SO_2 concentration also tends to be independent of distance from the stack in the range of 2 to 20 km. Maxima observed within 2 km of the stack have been less than those observed beyond 2 km by about a factor of 5. To date, the maximum expected from model calculations under conditions of strong convective instability has not been observed.

Model validation

The Gaussian model predictions of 1-h and 3-h averages for both SO_2 and tracer concentrations at fixed ground level stations are very imprecise. The correlation between the actual and predicted values is very poor (correlation less than 0.1). These findings indicate that plume model estimates of short-term exposure at fixed receptors are grossly unreliable.

Model predictions of the cumulative frequency distribution of maximum 1-h ground level concentrations failed to reproduce the observed distributions according to statistical tests of bias and data fit. When tracer data were used, the models tended to underpredict the median, upper quartile, and maximum of the maxima concentrations; individual predictions of maximum 1-h concentrations were within a factor of 2 of the observed maximum approximately 50% of the time.

Model predictions of the location and width of the plume at ground level, the so-called plume footprint, showed little or no precision. When surface meteorology and stability criteria inputs to the models were used, predicted plume axis location was regularly in error by more than 20° of azimuth, and plume width was regularly underpredicted by a factor of 2 or more.

These analyses have been designed to test the precision of the models when they are exercised according to current operational guidelines. Further analyses are required to pinpoint the causes of erratic model performance. These results do, however, provide a first measure of the reliability of the models as presently constructed and used for operational purposes.

The results will be presented to the EPA Guidelines Conference to be held in July 1981. Conferences on this topic are mandated by the Clean Air Act of 1977. *Project Manager: Glenn Hilst*

R&D Status Report
NUCLEAR POWER DIVISION

John J. Taylor, Director

COOLING GARMENTS FOR PLANT MAINTENANCE

An EPRI-sponsored human factors review of power plant maintainability has confirmed that the high-temperature conditions typical of a nuclear plant maintenance environment pose a number of serious problems (RP1126). These conditions constrain the duration and intensity of work, affect the efficiency and morale of personnel, and on occasion may jeopardize their safety and health. It is not uncommon for a worker's exposure to high temperatures to be limited to approximately 30–40 min, well under typical radiation exposure constraints. In response to this problem, EPRI has funded a project to design, construct, and test nonrestricting cooling systems to protect workers against extremely hot temperatures (RP1705).

Prototype cooling systems

Two cooling systems were evaluated. One, designed and constructed for this study, cools by small packets of ice configured close to the trunk of the body. The other, selected as representative of systems commercially available to the nuclear industry, cools by circulating a liquid over the head and trunk area.

To ensure that the rigorous demands of a nuclear power plant maintenance environment were satisfied, several cooling-system criteria were established. The primary requirement is that the system enable a worker to tolerate heat stress for two hours. A successful cooling system must also be compatible with other protective equipment (radiation protection clothing, self-contained breathing apparatus, safety harnesses); simple in design and low in cost; durable; washable and easy to decontaminate; easy to put on, comfortable, and not restrictive of movement.

The prototype frozen-water garment (FWG), the last of several versions tested, consists of a shirt and shorts made of an insulating material (Tinsulate) and connected at the waist; the garment covers the trunk, half of the thighs, and half of the upper arms (Figure 1). Attached to the side of the garment (by Velcro strips) are many small ice packets (small bags made of lightweight nylon that are filled with water and frozen). A garment containing all the ice packets weighs 7.25 kg (16 lb).

In the circulating-liquid garment (CLG), a solution of propylene glycol and water is circulated through a system of capillaries in a vest covering the back and chest and a hood covering the head. The capillaries are made of urethane-coated nylon. A battery-driven motor worn on a belt circulates the liquid, which is cooled as it passes through two canisters containing a frozen solution of water and alcohol. The canisters, each measuring approximately 18 × 13 × 5 cm (7 × 5 × 2 in), provide about 25 min of cooling; they are attached one above the other to the chest side of the vest. The total weight of this system is also approximately 7.25 kg (16 lb).

Laboratory tests

Testing was conducted in a climatic chamber under controlled conditions that simulated the ambient temperature, relative humidity, and air speed found in a containment

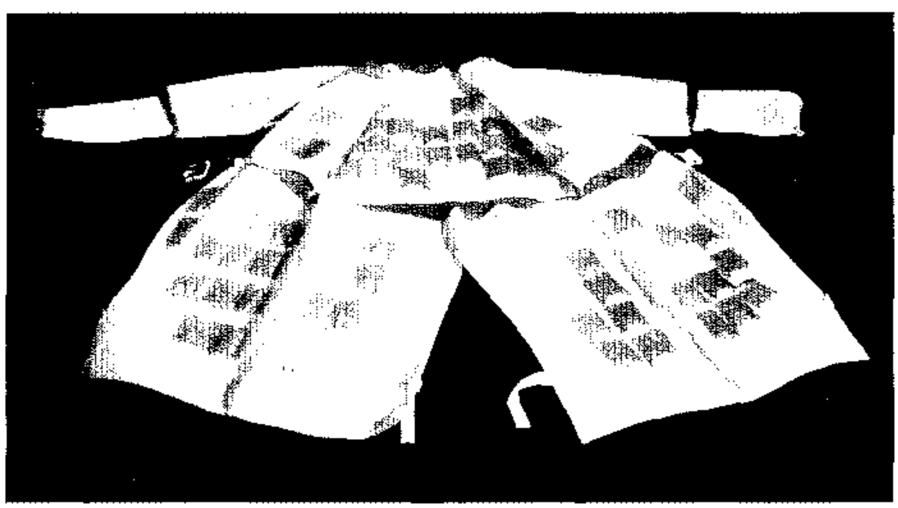


Figure 1 Prototype frozen-water garment for extending the safe working periods of maintenance personnel in high-temperature environments. Cooling is accomplished by small ice packets attached to the inside of the Tinsulate garment.

work situation. Measurements made during an entry into containment at Duke Power Co.'s Oconee station were used to establish the conditions. For all test sessions the dry-bulb temperature was 55°C (131°F), the relative humidity was 28%, and the air speed was 0.2 m/s.

Five medically screened subjects with an average age of 25 participated in the study. While in the test chamber, the subjects alternated between walking on a treadmill and sitting. The metabolic demand of these activities is equivalent to that measured for typical maintenance tasks at Oconee (climbing, light arm work).

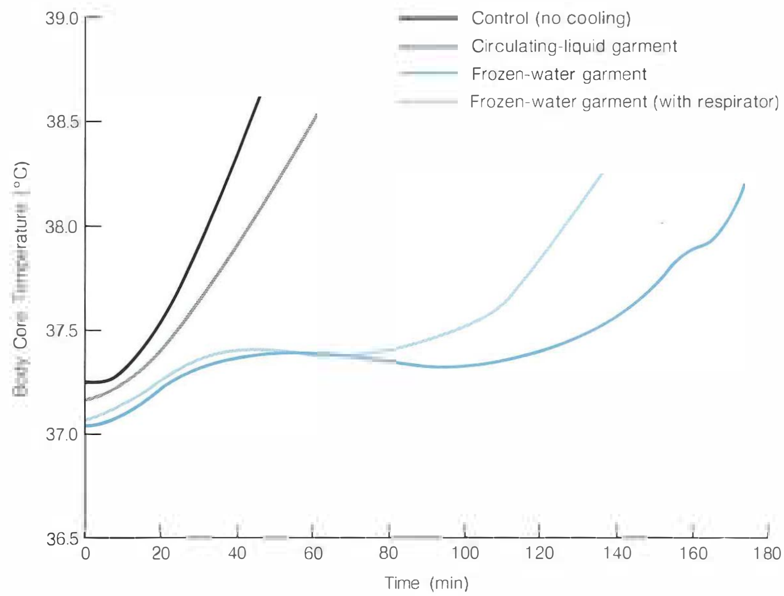
The subjects wore a standard ensemble of radiation protection clothing during all cooling-system tests and during the control runs, when no cooling system was used. The FWG was worn under the radiation protection clothing but was separated from the skin by underwear. The CLG (both vest and hood) was also worn under the radiation clothing except for the ice canisters, which were carried outside the cotton coveralls to facilitate replacement during testing. The first CLG test subject wore underwear; in accordance with the manufacturer's recommendations, the remaining subjects did not. In some tests of the FWG, the subjects also wore a respirator and an air supply cylinder (the respirator was not used for breathing but only to simulate load).

Standard physiological data—body core temperature (as measured by a rectal thermistor), heart rate, and skin temperature—were collected continuously during each test session. Also, the subjects were asked to rate thermal sensation and discomfort every 15 min.

Each test session was terminated when the subject felt dizzy, weak, or nauseous or when core temperature reached 39°C (102°F) and/or heart rate exceeded 160 beats/min. On the basis of these criteria, the mean exposure tolerance was 52 min for controls, 70 min for subjects who were wearing the CLG, and 178 min for those wearing the FWG. In runs in which subjects wearing the FWG either performed more demanding work or wore a respirator, exposure times of 114 min and 137 min, respectively, were recorded. Control or CLG trials were not run for these two conditions.

Figure 2 summarizes the data on core temperature obtained during the tests. Subjects without cooling experienced a steady rise in core temperature and feelings of discomfort, and they elected to terminate exposure before their temperature reached the safe limit of 39°C. Results were similar for subjects wearing the CLG. For those wearing the FWG without a respirator, however, core temperature leveled off for a period after slight initial rise; these subjects were able to tolerate the hot environment for an additional 120 min. Similar results were obtained for the other two physiological measures: heart rate and skin temperature.

Figure 2 Body core temperature as a function of time at a relative humidity of 64% (55°C dry-bulb temperature; 35°C wet-bulb temperature). The frozen-water garment enabled test subjects to tolerate the hot environment for an additional 2 h.



FWG field test

On the basis of the laboratory results, a limited field test of the FWG was conducted during an outage at the Oconee station. In the test two subjects wearing the cooling garment and two control subjects performed light work in the containment penetration area at an ambient temperature of 38°C (100°F). Results indicate that the FWG was helpful in delaying a rise in core temperature and heart rate and in extending the time workers could be exposed to the high temperature without ill effects or feelings of discomfort. For example, the two control subjects could scarcely tolerate 1 h of work; before they left the area, their core temperature had reached 39°C and one had a heart rate of 190/min. In contrast, one worker who wore the FWG tolerated 1.5 h with no difficulty; his temperature reached only 38°C and his heart rate was only 145/min at termination. Inadequate freezer capacity prevented freezing of all ice packets in this test, and the worker's exposure might have been even longer had all the ice packets been frozen solid.

The cooling capacity shown by the FWG in the laboratory was confirmed at Oconee. Both the laboratory and field results indicate that the FWG can achieve the objective of 2 h of heat stress tolerance. However, the field test demonstrated the need for the following design modifications to make the system more practical.

- Better attachment of the ice packets to the garment
- Stronger packets to prevent breakage and liquid spills
- Changes in the distribution of the ice packets to allow the worker to lie on his back or side

□ Adjustable garment size so the garment will fit a more diverse population

□ Changes to enable the worker to put on the garment more quickly and with minimal help

These improvements are now being made, and they will be validated in the near future through more extensive field testing. Once these tests are completed, guidelines for preparing a specification will be drawn up so that utilities can pursue procurement of these garments from prospective suppliers. *Project Manager: John O'Brien*

TRANSIENT FUEL BEHAVIOR ANALYSIS

EPRI-sponsored research on transient fuel behavior analysis is divided into three broad efforts, which involve planning, methodology development, and methodology application. First, various fuel-related state-of-the-art assessment and safety studies have been or are being conducted to support research planning and to provide background information for use by utilities in the licensing process (RP1117). Second, a methodology is being developed for performing realistic and licensing calculations for all four LWR vendor designs, and a data base is being compiled for verifying the methodology (RP1321). Third, sample applications are being performed to assess the methodology and enhance technology transfer (RP1627).

State-of-the-art assessment and safety studies

Various studies have been completed in the last two years. One investigated requirements for analyzing transient fuel rod behavior during design basis events. The report (NP-1022) identifies the regulations that pertain to transient fuel rod behavior, describes the range of design basis events considered in the licensing process, and discusses requirements for modeling transient fuel behavior. It also provides guidelines for evaluating a transient fuel behavior computer code for plant licensing applications and uses them to assess FRAP-T, NRC's transient fuel behavior code. The report serves as a planning document for the analytic methods development work discussed below. and it has also been used in planning the reload methodology (RP1761).

Another report (NP-1210) describes an analysis of the interaction between heat transfer and fuel behavior (specifically, cladding swelling) under hypothetical LOCA reflood conditions. For this analysis, selected models describing the transient fuel behavior were added to the thermal-hydraulic computer code COBRA. The results obtained were in excellent agreement with data from experiments on dynamic fuel behavior and thermal hydraulics conducted in the Federal Republic of Germany.

In another study (NP-1495) the one- and two-dimensional versions of EPRI's continuum mechanics computer code STEALTH (NP-260) were used to simulate transient fuel rod response. The two-dimensional STEALTH calculations for the FRAP-T sample problem (a LOCA blowdown) showed a time-dependent pressure difference between the fuel rod plenum and the fuel rod hot spot that was not indicated by the NRC code. The STEALTH results were consistent with the COBRA results reported in NP-1210. The gas flow models used in FRAP-T, STEALTH, and COBRA are essentially the same in terms of physics; however, they are implemented differently. FRAP-T uses a two-point implementation (plenum and hot spot), while STEALTH and COBRA act between adjacent axial nodes. As a result of their more rigorous implementation of the axial gas flow model, STEALTH and COBRA predict a lower internal pressure at the hot spot. This implies that the local driving force for cladding deformation is smaller (and therefore core blockage is likely to be less severe) than conservative licensing models would predict with instantaneous equalization of gas pressure.

Two other state-of-the-art studies are under way. One, involving reactivity insertion accident failure thresholds, will look at data from recent NRC-sponsored tests at the Power Burst Facility in Idaho and from over 300 tests conducted by the Japan Atomic Energy Research Institute. (The current NRC standard in this area, Regulation Guide 1.77, was written before these tests.) The other study involves Zircaloy failure mechanisms. One issue it will consider is that discussed in NUREG-0630—cladding swelling and rupture models for LOCA analysis. The modeling of Zircaloy failure mechanisms has been scoped conservatively, but a realistic understanding of the phenomena associated with failure above 1083 K (1490°F) is needed.

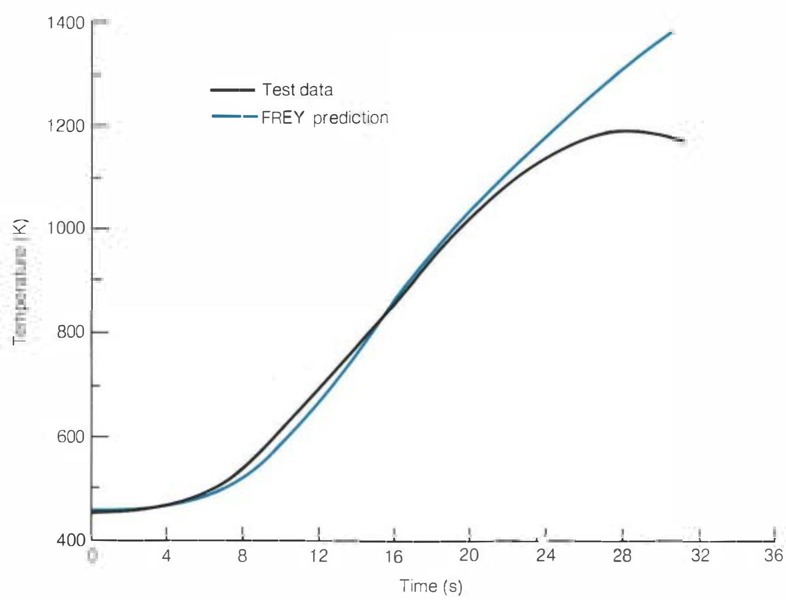


Figure 3 Temperature response for the FRF-1 test at Idaho National Engineering Laboratory. Comparison of FREY calculations with test data taken at one of the thermocouples shows good agreement.

Methodology development

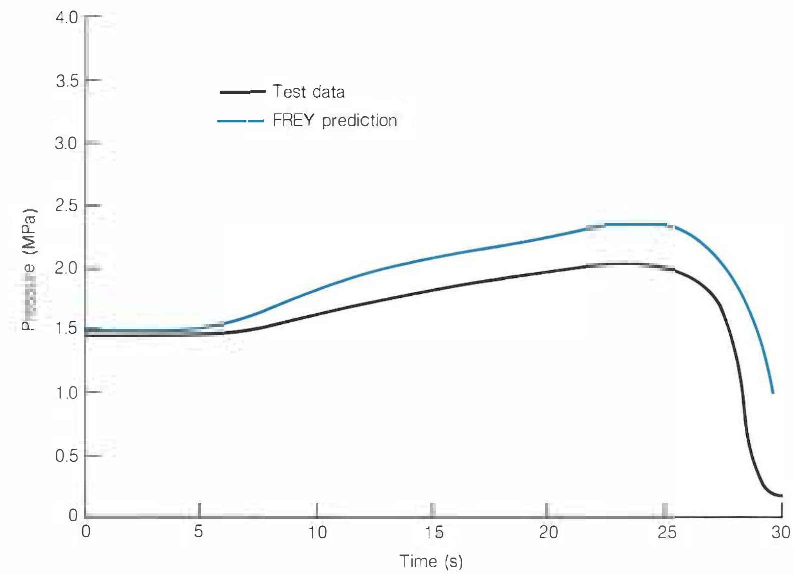
Two efforts have been completed in this area. One (NP-1224) involved a feasibility study for a plasticity model to describe the transient thermomechanical behavior of Zircaloy. In the other, the use of transfer functions to analyze thermal aspects of transient fuel rod behavior was investigated. This work has demonstrated efficiencies for an application that needs longer rather than shorter time steps. A final report is being prepared.

The major effort in this area involves the development of the computer code FREY to describe transient fuel behavior. FREY has four basic components. The mechanical description is based on CREEP–PLAST, a finite element, implicit, computer program developed at General Electric Co. under the sponsorship of the U.S. Atomic Energy Commission (AEC). The thermal description is based on another AEC-sponsored finite element, implicit, program, COYOTE, developed at Sandia Laboratories. The material properties description is based on MATPRO, developed at Idaho National Engineering Laboratory (INEL) under NRC sponsorship. The heat transfer correlation package is from RETRAN–RELAP, developed by Energy Incorporated–INEL under EPRI–NRC sponsorship. (EPRI's RETRAN, CCM-5, used a version of RELAP as a starting point.) These four elements have been upgraded and integrated, and a single-fuel-rod version of FREY is now undergoing testing and debugging.

Limited assessment and applications work on FREY is being conducted by EPRI staff and contractors. Figures 3, 4, and 5 show the results of FREY calculations of the FRF-1 test, power ramp to burst, performed in the Treat reactor at INEL. Figure 3 shows the temperature ramp at one thermocouple measurement location and compares the data with the FREY calculations. There is uncertainty about the experimental conditions late in the ramp. When this test is added to the EPRI transient fuel behavior data base discussed below, the contractor will attempt to resolve the uncertainty and this will allow a more accurate judgment about the code's ability to simulate the experiment.

Figure 4 presents the test data and code calculations on internal rod pressure. The data show a gradual increase in pressure with time (caused by the heating of the internal fill gas during the power ramp), followed by a pressure decline (caused by an increase in fuel rod volume during cladding

Figure 4 Fuel rod plenum pressure for the FRF-1 test.



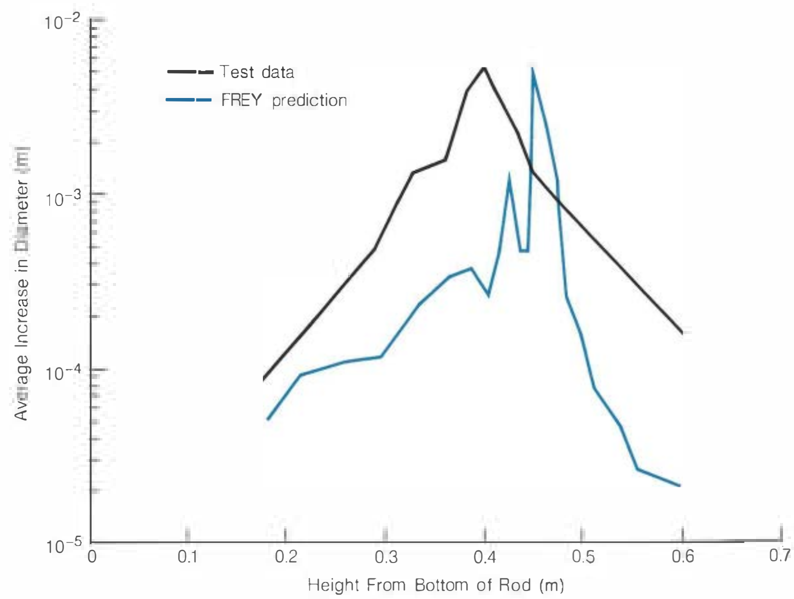


Figure 5 Fuel rod diametral increase with power ramp. FREY calculations of diameter immediately prior to rod failure are compared with measurements made in a posttest examination.

deformation), and finally, total depressurization upon cladding failure.

Figure 5 compares the posttest axial variation of the fuel rod diameter with the calculated diameter at failure. The comparisons shown in the figures represent a limited initial evaluation of the FREY code, and agreement is good for each of the three test parameters.

To make FREY as machine-independent as possible, the current CDC computer version of the code is being adapted for an IBM computer. Both versions are expected to be available for prerelease to a utility users group by early fall of this year.

A data base on transient fuel behavior is being compiled for use in qualifying and verifying the FREY code. A framework has been developed for the base, which is called ERUDITE, and some initial data have been entered. ERUDITE will be well documented, will consist primarily of transient data, and will be subjected to significant quality assurance work. The sources of the experimental data for the base are U.S. government and foreign safety tests. ERUDITE is described in NP-1766-CCM and will be available through the Electric Power Software Center.

In related work (NP-1202), the NRC-sponsored Power Burst Facility test program was evaluated as a source of data for qualifying fuel behavior codes. The requirements for analyzing transient fuel behavior that were identified in NP-1022 were used as the basis of evaluation.

Methodology assessment and application

EPRI's assessment and applications efforts are just getting under way. Emphasis at this time is on debugging, sample applications, and preliminary qualification of the FREY code. Oregon State University is the only current user of ERUDITE. In addition, OSU will use FREY to run excess load, seized pump shaft, control rod drop, and zero-power control rod ejection problems for a Combustion Engineering, Inc., PWR.

Other applications of FREY are also planned, including the following studies: control rod withdrawal, four-pump flow coastdown, and locked-rotor cases on a Babcock & Wilcox Co. PWR; PWR control rod ejection, loss of load, and depressurization transient cases; BWR subcooling–power ramp and pressurization–power excursion cases; and Westinghouse Electric Corp. PWR control rod withdrawal and boron dilution cases.

EPRI is now ready to initiate transfer of this technology, and utilities interested in joining a FREY users group are encouraged to write or call the project manager. Participation in the assessment and enhancement of FREY is viewed as a way EPRI members can maximize their investment in this research. *Project Manager: Richard Oehlberg*

New Contracts

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
Coal Combustion Systems				
RP1030-16	Sulfur Meter Evaluation, Monroe Plant	5 months	65.4	Science Applications, Inc. *O. Tassicker*
RP1030-17	Sulfur Meter Evaluation, Monroe Plant	8 months	26.6	Bechtel Corp. *O. Tassicker*
RP1260-22	Planning Study: Cooling Tower Test Facility	10 months	50.8	Environmental Systems Corp. *H. Reilly*
RP1266-23	Noise Control Costs and Benefits in Fossil Power Plants	7 months	61.6	Hoover-Keith Associates, Inc. *A. Armor*
RP1857-1	Limestone Flue Gas Desulfurization Systems Data Book	13 months	242.8	Black & Veatch Consulting Engineers *C. Dene*
RP1871-2	Corrosion/Erosion, Laboratory and Field Testing	30 months	328.2	Battelle, Columbus Laboratories *C. Dene*
Electrical Systems				
RP1780-1	Development of Improved Tree Trimming Equipment and Techniques, Phase 1	11 months	214.4	Asplundh Environmental Services *R. Tackaberry*
RP1944-1	Optimization of Induction Motor Efficiency	2 years	224.6	University of Colorado *J White*
Energy Analysis and Environment				
RP1630-15	Preparation of Data Volumes for SURE Aircraft Measurements	2 months	9.4	Meteorology Research, Inc. *G. Hilst*
RP1795-1	Sampling Airborne Organics—Artifact Problems	15 months	99.8	Environmental Research & Technology, Inc. *J. Guertin*
RP1824-5	R&D Planning Assistance for the EPRI Occupational Health Program	10 months	24.3	Applied Decision Analysis, Inc. *L. Sagan*
RP1907-1	Acid Deposition–Forest Canopy Interactions	3 years	551.7	Union Carbide Corp. *J. Huckabee*
Energy Management and Utilization				
RP1085-6	Development of Ceramic Materials for Molten Carbonate Fuel Cells	2 years	287.2	Ceramatec, Inc. *J. Appleby*
RP1085-7	Investigation—Sintering of Copper and Alloys	3 years	136.1	Northwestern University *A. Appleby*
RP1201-18	Heating of Forging Billets, Using Pulsed Homopolar Power Supplies	6 months	32.1	University of Texas at Austin *L. Harry*
RP1201-19	Energy Roof Systems Study	5 months	43.8	Altas Corp. *G. Purcell*
RP1201-21	Research Strategy: Residential, Commercial, and Apartment Conservation Service Program	5 months	43.9	Applied Management Sciences, Inc. *A. Lannus*
RP1524-6	System to Collect Information and Transfer Technology for Large-Scale EV Fleet Demonstrations	1 year	200.0	Purdue Research Foundation *J. Mader*
RP1677-5	Portfolio Analysis of Prospective Users of Fuel Cell Power Plant	5 months	84.0	Burns & McDonnell Engineering Co. *D. Rigney*
Nuclear Power				
RP606-9	Independent Review to Identify Critical Components in a Production Prototype Vessel Imaging System	20 months	26.7	Amdata Systems, Inc. *J. Quinn*
RP1074-2	Validation of Resonance Shielding Factors for Benchmark Analysis	11 months	22.0	Technion Research and Development Foundation, Ltd. *O. Ozer*
RP1163-2	U-Tube Steam Generator Modeling for Modular Modeling System	2 months	25.0	Systems Control, Inc. *S. Kalra, M. Toren*
RP1178-2	Advanced Recycle Methodology Program	10 months	68.9	Science Applications, Inc. *W. Eich*

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
RP1391-5	Data System Quantitative Techniques	6 months	161.5	The S. M. Stoller Corp. *J. Huzdovich*
RP1543-1	Fracture Toughness Characterization of Nuclear Pump and Valve Material	7 months	55.7	Fracture Control Corp. *R. Nickell*
RP1543-2	Effects of Residual Stress on the Ultrasonic Testing Detectability of Surface Cracks in Feedwater Nozzles	10 months	74.7	Anatech International Corp. *R. Nickell*
RP1561-1	BWR Plant Transient Data Collection and Analysis	9 months	80.1	S. Levy, Inc. *P. Bailey*
RP1567-1	Component Wear Measurements	9 months	92.0	Battelle, Columbus Laboratories *M. Naughton*
RP1568-1	Solid Radwaste Radioisotope Measurements	9 months	83.4	NWT Corp. *M. Naughton*
RP1585-2	Improvement of LWR Designs	8 months	25.0	S. Levy, Inc. *L. Martel*
RP1586-1	Ductile Support Design of Pipe Systems	22 months	312.0	University of California at Berkeley *Y. Tang*
RP1627-3	Assessment and Application of Transient Fuel Behavior Computer Codes	1 month	16.6	Exxon Nuclear Co., Inc. *R. Oehlberg*
RP1690-2	Upgrade of PDQ-7 Environmental Library	10 months	51.1	Energy Incorporated *W. Eich*
RP1731-2	Modeling of Natural Circulation Phenomena in Nuclear Reactor Cooling Loops	1 year	30.4	Technion Research and Development Foundation, Ltd. *J. Sursock*
RP1741-3	Development of Efficient Numerical Methods for Three-Dimensional Two-Phase Flow	6 months	100.0	Jaycor *S. Srikantiah*
RP1932-7	Hydrogen Control Studies	7 months	151.0	Acurex Corp. *L. Thompson*
RP1933-1	Prediction of LWR System and Containment Behavior During Postulated Severe Accidents	15 months	182.5	Science Applications, Inc. *O. Ozer*
RP2014-1	Analysis of Fluid-Structure Interaction in PWRs and BWRs	1 year	57.3	Northwestern University *C. Chan*

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.

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ADVANCED POWER SYSTEMS

Determination of Procedures for Transmutation of Fission-Product Wastes by Fusion Neutrons

AP-1642 Final Report, Vol. 3 (RP474-2); $11.25

This volume summarizes the neutronic aspects of fission-product transmutation in fusion reactor blankets. Computation methods and nuclear data—transmutation calculations and chains—are discussed, and details are provided on the potential half-life and toxicity reductions, including burnup calculations, the number of fusion burner reactors required, and the changes in the isotopic composition of the blanket during transmutation. The contractor is the University of Texas at Austin. *EPRI Project Manager: N. A. Amherd*

Ceramic Materials for Fusion Reactors

AP-1702 Interim Report (RP992); $6.50

This report presents results from a study of the application of ceramic materials in fusion plants. It discusses systems design considerations, nuclear design analysis, mechanical and thermal design, and design analysis applications. Details are provided on materials evaluation and environmental testing, bonded silicon carbide joints, and neutron irradiation experiments. The contractors are General Atomic Co., General Electric Co., and Rensselaer Polytechnic Institute. *EPRI Project Managers: D. J. Paul and W. T. Bakker*

Economic Evaluation of Coal Gasification for Electric Power Generation: An Update

AP-1725 Final Report (RP239-2); $7.25

This economic update of previous gasification–combined-cycle power plant studies presents capital and operating costs for all systems in 1978 dollars. For comparative purposes, total capital requirements and cost of electricity have been included for both subcritical and supercritical coal-fired steam plants with flue gas desulfurization. The results of this study indicate that installed plant costs have escalated by 11–19% since mid-1976. The contractor is Fluor Engineers and Constructors, Inc. *EPRI Project Manager: E. L. Force*

Moving-Bed Gasification–Combined-Cycle Control Study: Results and Conclusions —Case 1, Air-Blown Dry-Ash Operation

AP-1740 Final Report, Vol. 1 (RP914-1); $5.25

Computer simulation has been used to investigate the inherent process dynamics of an integrated coal gasification–combined-cycle (GCC) power plant and the control strategies required for successful operation under load-changing conditions. This volume presents results from a control analysis of a GCC power plant based on a moving-bed gasifier operated in the air-blown dry-ash mode. The contractor is General Electric Co. *EPRI Project Manager: G. H. Quentin*

Definition of a Small Fusion Reactor: TRACT

AP-1752 Final Report (RP922-4); $8.75

In this Phase 1 summary report, a magnetic fusion reactor concept called TRACT (triggered reconnection, adiabatically compressed toroid) is examined as a candidate for a small fusion reactor. A preliminary conceptual design of a TRACT fusion power pilot plant with all the relevant components is provided, and key issues to be resolved are identified. Three possible development programs of varying risks are presented. The contractors are Mathematical Sciences Northwest, Inc.; Bechtel National, Inc.; and Puget Sound Power & Light Co. *EPRI Project Managers: F. R. Scott and D. J. Paul*

Solvent-Refined Coal Process: Operation of SRC Pilot Plant, Wilsonville, Alabama

AP-1784 Annual Report (RP1234-1-2); $8.75

Operating conditions and results are summarized for tests conducted during 1979 at the 6-t/d SRC pilot plant in Wilsonville, Alabama, with emphasis on work completed in the fourth quarter. Kentucky 6, 9, and 11 coals were processed; mineral separation techniques studied included critical solvent de-ashing and vertical leaf filtration. *EPRI Project Manager: H. E. Lebowitz*

COAL COMBUSTION SYSTEMS

Instrument and Control Technician Curriculum Planning Guide

CS-1537 Final Report (RP1266-6); $8.75

This report presents a detailed inventory of the skills and knowledge needed by an instrumentation and control technician. The task inventory forms the basis of a model two-year curriculum, which reflects ideas from representatives of various power plants and postsecondary, vocational, and technical institutions. Descriptions and outlines are supplied for each course and its component modules; preceding each instructional module is a list of learning objectives based on job performance requirements. The contractor is the Center for Occupational Research and Development. *EPRI Project Managers: J. P. Dimmer and K. P. Lehner*

Evaluation of Chiyoda Thoroughbred-121 FGD Process and Gypsum Stacking

CS-1579 Final Report, Addendum to Vol. 3 (RP536-4); $2.75

Stacked gypsum from the Chiyoda Thoroughbred-121 flue gas desulfurization process was monitored for one year. This addendum presents the results of geotechnical laboratory testing and visual inspections of the gypsum at the end of that period, as well as the results of groundwater monitoring. The aging and weathering characteristics of the gypsum are described. The test results show no measurable long-term change in shear strength or permeability of the stacked gypsum; water quality in the aquifers was either unchanged or slightly improved. The contractor is Ardaman & Associates, Inc. *EPRI Project Manager: T. M. Morasky*

Studies on Mathematical Models for Characterizing Plume and Drift Behavior From Cooling Towers: Executive Summary

CS-1683-SY Summary Report (RP906-1); $2.00

This report summarizes the contents of a five-volume work on new models for predicting plume rise and drift deposition from single and multiple natural-draft and mechanical-draft cooling towers. The contractor is Argonne National Laboratory. *EPRI Project Manager: J. A. Bartz*

Construction Materials for Wet Scrubbers

CS-1736 Final Report (RP982-14); Vol. 1, $6.50; Vol. 2, $11.25

This report presents results from a survey of utility industry experience regarding construction materials at full-scale lime and limestone wet scrubber flue gas desulfurization installations. Volume 1 describes the failure histories of various materials, discusses reasons for their success or failure, and presents relative costs of the materials. Components are categorized according to whether their materials failure histories indicate minimal, moderate, or significant and critical problems. Volume 2 contains detailed reports of the site visits. It lists the personnel interviewed; describes the specific process, design, reliability, and materials data gathered; and presents summary comments for each installation. *EPRI Project Manager: R. G. Rhudy*

Aqueous Carbonate Process Test Requirements Documents

CS-1738 Final Report (RP1458-1); $3.50

EPRI is cosponsoring a commercial-size (100-MW) demonstration of the aqueous carbonate process, a regenerable flue gas desulfurization technique. This report presents the testing and data requirements identified and agreed upon by the demonstration cosponsors. These requirements are compared with the vendor-proposed process capabilities, and the resolution of differences is reviewed. A process flow diagram and a preliminary test schedule are included. *EPRI Project Manager: R. G. Rhudy*

Scrubber-Generated-Particulate Literature Survey

CS-1739 Final Report (RP982-11); $5.75

This report describes a literature survey to determine what research has been performed in the area of scrubber-generated particulates. The four major tasks of this effort—data base development, telephone interviewing, data evaluation, and reporting of results—are detailed. Information obtained on applicable sampling and analysis methods, mist eliminator efficiency, particulate removal, and scrubber emissions is presented. The contractor is TRW, Inc. *EPRI Project Manager: R. G. Rhudy*

Bench-Scale Study of the Dry Removal of SO_2 With Nahcolite and Trona

CS-1744 Final Report (RP982-8); $5.25

The results of a bench-scale study on dry removal of SO_2 from the flue gas of coal-fired boilers are described and interpreted. The process parameters studied include flue gas temperature, SO_2 concentration, injection rate, sorbent particle size, residence time in the duct, and the location of sorbent injection. The results indicate that it may be possible to use this integrated dry injection process to meet EPA's New Source Performance Standards for SO_2 and particulate removal from flue gas. The contractor is KVB, Inc. *EPRI Project Manager: Richard Hooper*

Assessment of the Use of Human Factors in the Design of Fossil-Fired Steam Generating Systems

CS-1760 Final Report (RP1266-20); $5.75

A 14-month study was conducted to assess the use of established human factors engineering principles in the design of human-machine systems for fossil-fuel-fired utility plants. Three modern steam generating systems, each supplied by a different manufacturer, were evaluated. A methodology was developed by which a team of knowledgeable plant design and human factors specialists can perform a comprehensive human factors design evaluation of existing or future plants. The contractor is Whitston Associates. *EPRI Project Manager: J. P. Dimmer*

Recovery, Utilization, and Disposal of Solid By-products Generated by Dry Flue Gas Desulfurization Systems: State of the Art and Research Needs

CS-1765 Final Report (RP1260-16); $6.50

Dry flue gas desulfurization (FGD) technologies were reviewed, with emphasis on the more advanced processes, such as dry injection and spray drying. This report outlines the characteristics of dry FGD wastes and discusses proposed alternatives for their recovery, utilization, and ultimate disposal. The state of the art of dry FGD waste management is summarized; areas of insufficient information are identified; and recommendations for future R&D are made. The contractor is SCS Engineers. *EPRI Project Manager: R. Y. Komai*

Failure Cause Analysis: Feedwater Heaters

CS-1776 Final Report (RP1265-7); $8.75

A survey was conducted to define the major causes of feedwater heater failures. Data were gathered through a literature search, a questionnaire, visits to selected sites, and interviews with architect-engineers and heater vendors. Six major problem areas were identified: tube vibration, flashing in the drains' subcooler zone because of inadequate level control, tube inlet erosion, corrosion, steam impingement, and difficulty in plugging failed tubes. Recommendations for improvements were made. The contractor is International Energy Associates, Ltd. *EPRI Project Manager: I. A. Diaz-Tous*

Survey of the State of the Art of Coal Handling During Freezing Weather

CS-1780 Final Report (RP1265-9); $4.50

This report presents a state-of-the-art review of coal-handling procedures and programs used by electric utilities, coal mines, and coal transfer stations during periods of freezing weather. The use of freeze-conditioning agents to reduce coal-handling problems is discussed, as well as the relative efficacy of various nonchemical techniques. Guidelines for handling frozen coal that reflect typical problems and solutions are given. The contractor is Ford, Bacon & Davis. *EPRI Project Manager: I. A. Diaz-Tous*

ELECTRICAL SYSTEMS

Determining Load Characteristics for Transient Performance

EL-850 Final Report (RP849-1); Vol. 1, $3.50; Vol. 2, $3.50; Vol. 3, $3.50; Vol. 4, $4.50

Tests were conducted on three power systems to evaluate the accuracy of a prototype load-modeling procedure in modeling the dynamic power response of active and reactive loads when subjected to limited excursions of voltage and frequency. Volume 1 summarizes the results and discusses the research necessary to develop a production-grade load-modeling procedure. Volume 2 presents load-modeling guidelines developed in this effort and examines induction motor characteristics and their effect on system stability. Volume 3 identifies possible data sources for the load-modeling procedure and analyzes their usefulness in determining the composition of bus load by component. Volume 4 presents the results of the power system tests, as well as an evaluation of the load-modeling procedure. The contractor is General Electric Co. *EPRI Project Manager: J. V. Mitsche*

Real-Time Digital Data Acquisition System for Determining Load Characteristics: Instructions

EL-851 Final Report, Vol. 2 (RP849-2); $6.50

A real-time digital data acquisition system has been designed and developed for use in power system substations for recording and preprocessing of data on load response to variations in frequency and voltage. This volume presents operating instructions, a detailed technical discussion of software operation, installation and troubleshooting information, and a maintenance procedure for the system. A list of supporting documentation is included. The contractor is Institut de Recherche de l'Hydro-Québec. *EPRI Project Manager: D. F. Koenig*

Determination of Synchronous Machine Stability Study Models

EL-1424 Final Report, Vol. 1 (RP997-4); $7.25

A project was undertaken to experimentally determine generator model parameters in order to improve the accuracy of power system dynamic stability simulations. Results from actual switching tests were compared with results from (1) a computer simulation that used parameters obtained by standstill frequency response test methods, and (2) a simulation that used parameters based on manufacturer calculations. The contractor is Westinghouse Electric Corp. *EPRI Project Manager: D. T. Bewley*

Composite Wood Utility Poles

EL-1745 Final Report (RP796-1); $6.50

The development of durable, high-strength utility poles made of a composite wood material is described. Prototype 40-ft-long poles with a hollow octagonal cross section were made from chemically treated wood flakes bonded with a synthetic adhesive. This report discusses the advantages of these poles and the effects of such factors as wood species, flake type, flake alignment, adhesives, and preservatives. It presents designs for 40–100-ft poles, as well as cost projections. The contractor is Michigan Technological University. *EPRI Project Manager: R. S. Tackaberry*

Design of Multiprocessor Structures for Simulation of Power System Dynamics

EL-1756 Final Report (RP1355-1); $5.25

The use of microprocessors as an improved problem-solving method for power system simulations was investigated. This report describes the design of a network of computers arranged in a modified ring structure for solving (in parallel) equations describing dynamic disturbances on large power systems. The potential of the technique is examined, as well as its pitfalls; the results provide a foundation for the investigation of other scheduling and communication strategies and for an actual hardware demonstration of this technique. The contractor is Northwestern University. *EPRI Project Manager: J. V. Mitsche*

Magnetic Refrigerator Development

EL-1757 Final Report (RP7867-1); $5.75

This report describes tests of two magnetic refrigeration prototypes designed to provide more efficient refrigeration for superconducting technological applications in power generation and transmission. A gadolinium-metal magnetic-wheel model was tested at room temperature to examine its operation in an experimentally convenient temperature region, and tests were conducted on a simple reciprocating device to study its use in low-temperature applications. Results indicate that the prototypes' power output and efficiency fall short of the design goals and of the requirements for a practical refrigerator. The contractor is Los Alamos Scientific Laboratory. *EPRI Project Manager: Mario Rabinowitz*

Automatic Load Forecasting

EL-1758 Final Report (RP1355-5); $3.50

An advanced technique for automatically forecasting short-term (hourly) electric loads was developed and evaluated. Its performance was compared with that of models developed by using the more common Box-Jenkins method, and its advantages over the Box-Jenkins method were identified. The contractor is the University of Nebraska. *EPRI Project Manager: J. V. Mitsche*

Reliability Indexes for Power Systems
EL-1773 Final Report (RP1353-1); $11.25

This report reviews the traditional treatment of power system reliability indexes. It presents a qualitative analysis of both generation and transmission indexes, along with a detailed examination of the analytic and computation algorithms that have been developed. Also, the development of a unified probability framework for the definition of power system reliability indexes is discussed, various indexes are evaluated in terms of their usefulness, and the characteristics required for quantifying the worth of reliability are identified. The contractor is General Electric Co. *EPRI Project Manager: N. J. Balu*

System Control Performance
EL-1774 Final Report (RP1048-1); Vol. 1, $6.50; Vol. 2, $5.25; Vol. 3, $3.50; Vol. 4, $7.25

A project was undertaken to simulate the control of a power system in order to identify factors that affect economy and control. Volume 1, a technical manual, describes the computer program developed to determine cost-optimal dispatch that satisfies the regulating margin and other constraints (the Capacity Allocation Program). Results from tests of the program are presented, as well as operating guidelines, the system and operating data used, selected technical terms, and a discussion of the nontechnical causes of regulation error. Volume 2, a user's manual, describes the three programs that make up the Capacity Allocation Program—PPROC, XUPDATE, and DWLP. It provides input data requirements, job control languages, and program examples. Volume 3, a programmer's manual, includes a design overview; descriptions of solution methods, data structures, and routines; and information on testing, installation, and programmer support. Volume 4 contains the program listings for PPROC, XUPDATE, and DWLP. The contractor is Control Data Corp. *EPRI Project Manager: C. J. Frank*

ENERGY ANALYSIS AND ENVIRONMENT

Problems of Electric Utility Load Forecasting: Proceedings of the 1979 EPRI Load-Forecasting Symposium
EA-1729-SR Special Report; $12.50

The papers included in this report were presented at the second EPRI Symposium on Electric Utility Load Forecasting, which was held in June 1979. The symposium emphasized data problems faced by utilities, regulators' perspectives on forecasting, EPRI's efforts to enhance the flow of forecasting information, and hourly load forecasting. The contractor is Applied Forecasting & Analysis, Inc. *EPRI Project Manager: P. C. Gupta*

Comparison of Indoor and Outdoor Air Quality
EA-1733 Final Report (RP1309); $8.75

Data are presented from a comparative analysis of indoor and outdoor air pollutant concentrations in the Boston metropolitan area. The experimental design, monitoring procedures, numerical simulation of the indoor environment, and the concept of total exposure are summarized. The contractor is Geomet, Inc. *EPRI Project Manager: R. M. Perhac*

Coal Industry Problems
EA-1746 Final Report (RP1009-4); $4.50

This report synthesizes information obtained from interviews with a number of coal industry executives. The information indicates there is considerable concern about weak markets, excessive government regulation, and poor labor-management relations. Estimates for current mining costs are included. The contractor is Charles River Associates, Inc. *EPRI Project Manager: T. E. Browne*

Methodology for Assessing Population- and Ecosystem-Level Effects Related to Intake of Cooling Waters: Methodology Application to Cayuga Lake
EA-1749 Final Report (RP876); $5.75

This report describes a test application of previously developed analytic techniques for assessing the effects of cooling-water intakes on fish and invertebrate populations. Potential ecosystem effects at Cayuga Lake, New York, due to postulated power plant development were estimated. The results of initial analyses and an evaluation of the methodology's adequacy for use in a quantitative impact assessment are presented. The contractor is Lawler, Matusky & Skelly Engineers. *EPRI Project Manager: I. P. Murarka*

Atmospheric Effects of Cooling Lakes
EA-1762 Final Report (RP578); $5.75

The atmospheric effects of waste heat dissipation from cooling lakes operated in conjunction with power plants were assessed through a program of field measurements and analysis conducted at two Illinois sites during 1971–1973 and 1976–1978. (The earlier research was supported by the National Science Foundation.) The possible effects of cooling lakes on the initiation of steam fog and icing, the enhancement of convective clouds and precipitation, the downwind extent of temperature, and humidity plumes were analyzed. The contractor is the Illinois Institute of Natural Resources. *EPRI Project Manager: Charles Hakkarinen*

Preliminary Results From the EPRI Plume Model Validation Project: Plains Site
EA-1788-SY Summary Report (RP1616); $3.50

This report summarizes the model evaluations made during 1980 under EPRI's continuing plume model validation project, an effort designed to provide the data bases and analyses required for rigorous operational and scientific validation of plume models. The project's objectives and scope, the measurements acquired during spring and summer at the Kincaid power plant in Illinois, and data from calculations used to validate four Gaussian plume models (commonly used for regulatory and operational purposes) are presented. The contractor is TRC Environmental Consultants, Inc. *EPRI Project Manager: G. R. Hilst*

Aircraft Measurements of Pollutants and Meteorological Parameters During the Sulfate Regional Experiment (SURE) Program
EA-1909 Final Report (RP862-3); $8.75

The results of aircraft measurements of pollutant and meteorological parameters made during the Sulfate Regional Experiment are summarized. The report outlines the SURE aircraft program, gives the location, date, and time of each sampling flight, and describes analyses performed to date. The contractor is Meteorology Research, Inc. *EPRI Project Manager: G. R. Hilst*

Environmental Concerns in Rights-of-Way Management
WS-78-141 Proceedings; $25.75

This report contains 68 papers presented at a symposium on environmental concerns in rights-of-way (ROW) management held in October 1979. The papers, which discuss the experiences and objectives of utilities and environmental agencies regarding ROW management programs, are divided into three topic groups: routing considerations; ROW management, concepts, and guidelines; and wildlife research and management. The contractor is Mississippi State University. *EPRI Project Manager: J. W. Huckabee*

ENERGY MANAGEMENT AND UTILIZATION

Advanced Technology Fuel Cell Program
EM-1730 Final Report (RP114); $8.75

The results of a nine-year effort to develop an advanced fuel cell technology are presented. The report describes the various programs involved; details the development of molten carbonate fuel cells, advanced phosphoric acid fuel cells, and increased liquid fuel and coal fuel capabilities; and discusses power-conditioning investigations. The contractor is United Technologies Corp. *EPRI Project Manager: A. P. Fickett*

Advanced Technology Fuel Cell Program
EM-1730-SY Summary Report (RP114); $2.75

This report is an executive summary outlining a nine-year effort to develop an advanced fuel cell technology. It discusses fuel cell power plants for utility applications, the suitability of initial power plant technology, molten carbonate and advanced phosphoric acid fuel cells, improved fuel capabilities, and power-conditioning investigations. The contractor is United Technologies Corp. *EPRI Project Manager: A. P. Fickett*

EPRI Roles in Battery Commercialization
EM-1748 Final Report (RP1674-2); $13.50

This report presents an evaluation of the variety of roles that EPRI might take in facilitating battery commercialization. The study used a multiparty decision analysis model that determined the impact of each potential EPRI role on the battery supplier, the government, and the utility. The early battery market was quantified to provide data for the analytic model. Results detailing a number of alternatives for EPRI consideration are included. The contractor is Decision Focus, Inc. *EPRI Project Manager: J. R. Birk*

NUCLEAR POWER

Human Factors Review of Power Plant Maintainability

NP-1567 Final Report (RP1126); $13.50

The human factors aspects of power plant maintainability were evaluated at five nuclear plants and four fossil fuel plants. The methods used included a checklist-guided observation system, structured interviews with maintenance personnel, direct observations of maintenance tasks, reviews of procedures, and analyses of maintenance errors or accidents by means of the critical incident technique. The study revealed a wide variety of human factors problem areas, most of which are extensively photodocumented. The contractor is Lockheed Missiles & Space Co., Inc. *EPRI Project Manager: H. L. Parris*

Temperature Dependence of the Multiplication Factor in LWR Lattices

NP-1694 Final Report (RP709-1); $4.50

The temperature dependence of the neutron multiplication in typical BWR and PWR unit cells was determined as a function of fuel depletion when fuel temperature was increased from 800 to 1200 K. The changes in cross-section (with increased temperature) of the principal isotopes of uranium and plutonium and of some fission products were taken into account simultaneously in the lattice analysis by very detailed resonance profile tabulations in the resolved resonance region of each nuclide. The contractor is Technion–Israel Institute of Technology. *EPRI Project Manager: Odelli Ozer*

NSSS Design and Cycle 1 Operating History Data for Arkansas Nuclear One, Unit 2

NP-1707 Final Report (RP1385-1); $7.25

This report contains design and cycle 1 operating data for the nuclear steam supply system (NSSS) of Arkansas Nuclear One, Unit 2. The design data include descriptions of the reactor core, the reactor coolant system, and NSSS control systems. Operating data are provided for the period December 1978–January 1980; the most important are reactor power, cumulative fuel burnup, control rod position, primary coolant temperature, and a series of power distribution state points. The contractor is Combustion Engineering, Inc. *EPRI Project Managers: J. A. Naser and R. N. Whitesel*

Thermal-Hydraulic Characteristics of a Westinghouse Model F Steam Generator

NP-1719 Interim Report (RPS129-1); Vol. 1, $5.25; Vol. 2, $9.50

CALIPSOS, a three-dimensional flow distribution code, was used to determine the steady-state thermal-hydraulic characteristics of a Westinghouse Model F steam generator at full, intermediate, and low power. Volume 1 describes the CALIPSOS model, as well as the assumptions, operating parameters, and transport correlations used, and presents selected graphical results. Volume 2 presents complete numerical results and guidelines for reading and interpreting them. The contractor is Combustion Engineering, Inc. *EPRI Project Manager: D. A. Steininger*

BWR 64-Rod-Bundle Blowdown Heat Transfer

NP-1720 Interim Report (RP495-1); $7.25

Experimental results from the 8 × 8 blowdown heat transfer phase of the BWR blowdown–emergency core cooling program are presented. BWR system performance and thermal response characteristics under postulated loss-of-coolant accident conditions were investigated in a scaled test apparatus. Effects of configuration changes on system response were identified, and test results were compared with predictions. The contractor is General Electric Co. *EPRI Project Manager: S. P. Kalra*

Thermal-Hydraulic Characteristics of a Westinghouse Model 51 Steam Generator

NP-1721 Interim Report (RPS129-1); Vol. 1, $5.25; Vol. 2, $9.50

CALIPSOS, a three-dimensional flow distribution code, was used to determine the steady-state thermal-hydraulic characteristics of a Westinghouse Model 51 steam generator at full, intermediate, and low power. Volume 1 describes the CALIPSOS model, as well as the assumptions, operating parameters, and transport correlations used, and presents selected graphical results. Volume 2 presents complete numerical results and guidelines for reading and interpreting them. The contractor is Combustion Engineering, Inc. *EPRI Project Manager: D. A. Steininger*

SIMQUAKE I: An Explosive Test Series Designed to Simulate the Effects of Earthquakelike Ground Motions on Nuclear Power Plant Models

NP-1728 Summary Report, Vol. 1 (RP810); $8.75

This summary report describes an extensive series of dynamic soil-structure interaction experiments (SIMQUAKE) on five scale models of nuclear containment buildings. It covers the experimental objectives and design, measured data, and major observations. The controlled data base provided by the SIMQUAKE and forced-vibration tests yields significant observations on model response, as well as insights on the limitations of certain numerical methods in nonlinear simulations. The contractors are the University of New Mexico; Civil Systems, Inc.; and ANCO Engineering, Inc. *EPRI Project Manager: Conway Chan*

Ignitability of High-Fire-Point Liquid Spills

NP-1731 Final Report (RP1165-1); $4.50

Conditions were identified under which a spill of flammable liquid on an ambient temperature floor could represent a fire threat to grouped cables in an electric utility installation. Five high-fire-point flammable hydrocarbon liquids and three floor materials were tested. The five factors on which the fire hazard of a spill depends are described, and the relative importance of each factor is identified. The contractor is Factory Mutual Research Corp. *EPRI Project Manager: R. E. Swanson*

Development of a Two-Velocity Model for Transient Nonequilibrium Two-Phase Flow Based on the FAST Approach

NP-1732 Final Report (RP815); $4.50

This report describes the modification of the transient thermal-hydraulic code FAST (finite-interval analytic solution technique) to handle transient two-phase flows with unequal phase temperatures and velocities. The goal was to develop a code that could efficiently analyze channels with heat sources. Three sample problems and solutions are included to demonstrate some of the capabilities of the FAST approach. The contractor is the University of Waterloo. *EPRI Project Manager: Mati Merilo*

Development of a Plastic Fracture Methodology

NP-1734 Final Report (RP601-1); $8.75

Fracture criteria were investigated to determine a basis for plastic fracture mechanics assessments of nuclear pressure vessels and other components exhibiting fully ductile behavior. Criteria for crack initiation and stable crack growth were evaluated in terms of utility, accuracy, and economy, and a fracture mechanics methodology was developed and verified for ductile materials. The results demonstrated that many different fracture criteria can be used as the basis of a plastic fracture resistance curve approach. The contractor is Battelle, Columbus Laboratories. *EPRI Project Manager: T. U. Marston*

Methodology for Plastic Fracture

NP-1735 Final Report (RP601-2); $10.50

A 42-month program on nonlinear fracture mechanics was conducted to develop a capability for analyzing and predicting the fracture response of nuclear pressure-containing components in the ductile regime of material response. This report describes the three major phases of the work—selection, confirmation, and application of fracture parameters—and presents conclusions and recommendations. It evaluates the characterizing-parameter approach and discusses the development and application of an engineering methodology. The contractor is General Electric Co. *EPRI Project Managers: R. L. Jones, T. U. Marston, and R. E. Smith*

Dynamic Crack Propagation in Pipes

NP-1742 Interim Report (RP231-1); $7.25

Fundamental properties governing rapid crack propagation and crack arrest were studied by using measured crack velocities in a dynamic finite element code to generate dynamic stress intensity factors. The initiation and propagation of axial through-cracks in pressurized pipes were simulated with an elastic-plastic finite difference shell code coupled with a one-dimensional thermal-hydraulic code in order to compute the leakage and depressurization of the fluid. The contractor is the University of Washington. *EPRI Project Manager: John Carey*

Effect of Weld Parameters on Residual Stresses in BWR Piping Systems

NP-1743 Final Report (RP1174-1); $5.75

This report presents the results of finite element analysis studies that evaluated the effects of important welding variables on residual stress distribution. It examines (1) the effects of weld heat input, weld joint design, residual stress remedies, and material properties on residual stresses, and (2) the effects of potential pipe-cracking remedies, such as heat sink welding and backlay cladding, on residual stress distribution. Experimental results have confirmed that last-pass heat sink welding can be effective in producing favorable residual stress distributions. The contractor is Battelle, Columbus Laboratories. *EPRI Project Manager: A. J. Giannuzzi*

Review of Proposed Improvements, Including Filter/Vent of BWR Pressure-Suppression and PWR Ice Containments

NP-1747 Final Report (TPS80-721); $8.25

The state of the art of filter/vent improvements of BWR pressure-suppression containments and PWR ice containments was reviewed. This report presents a summary description of operating and planned containments, a review of improvements proposed to date, a brief review and update of the Reactor Safety Study, a design improvement strategy based on the dominant risk scenarios, and a set of recommendations. The contractor is S. Levy, Inc. *EPRI Project Manager: W. J. Bilanin*

Stochastic Modeling of On-Line BWR Stability

NP-1753 Interim Report (RP1387-1); $7.25

The dynamic data system technique, a discrete time-series method, was used to analyze and estimate the stability characteristics of BWR dynamics. The method was tested with both perturbed neutron noise data, where stability results compared favorably with other analyses, and unperturbed neutron noise data, where the results confirmed those of the perturbed data tests. A conceptual design of an on-line stability analyzer is also discussed. The contractor is the University of Wisconsin at Madison. *EPRI Project Manager: B. B. Chu*

Design, Assembly, and Testing of X-Ray Diffraction Stress Analyzer for Stainless Steel Pipes

NP-1754 Final Report (RPT107-1); $3.50

This report describes a project to develop and build an X-ray diffraction stress analyzer for the measurement of longitudinal stresses inside stainless steel pipes that are 10 inches in diameter or larger. Some of the factors that affect the performance of the instrument—focusing effects on the diffracted beams, detector sensitivity, and statistical effects on the output signal—are detailed. The contractor is Science Applications, Inc. *EPRI Project Manager: J. R. Quinn*

Simulation Study: Emergency Diesel Generator Availability

NP-1759 Interim Report (RP1386-1); $3.50

A computer simulation study of the availability of the emergency diesel generator (EDG) standby system of a nuclear power plant is described. Availability, or the probability that the EDG system is capable of supplying power on demand, is discussed in connection with individual EDG failure and repair rates, system configuration, and inspection and maintenance policies. The computer program developed to simulate the effects of these factors is described, and numerical illustrations are presented. The contractor is Systems Exploration, Inc. *EPRI Project Manager: B. B. Chu*

Evaluation of the Thermal Cross Sections of ^{239}Pu and ^{241}Pu

NP-1763 Final Report (RP707-1); $4.50

The thermal neutron cross sections of the isotopes ^{239}Pu and ^{241}Pu are evaluated in the thermal neutron energy region below 1.0 eV. Particular emphasis is placed on the determination of the energy dependence or shape of cross sections, as well as their absolute values at thermal energy. Reference experimental data sets, consisting of original data or condensations thereof, are developed for each nucleus of this evaluation. The contractor is Battelle, Pacific Northwest Laboratories. *EPRI Project Manager: Odelli Ozer*

EPRI Nuclear Safety and Analysis Research Program

NP-1764-SR Special Report; $2.75

This special report—a detailed, updated version of a previously published article (*Nuclear Safety*, July-August 1980)—describes the activities of the EPRI Nuclear Safety and Analysis Department. The department's program and subprogram areas are identified, and its recent major accomplishments, current emphases, and overall direction are discussed. *EPRI Project Managers: W. B. Loewenstein and A. G. Adamantiades*

ERUDITE User's Guide: EPRI-Utility Transient Fuel Behavior Data Information Source

NP-1766 Final Report (RP1321-3); $7.25

The initial version of the EPRI data base on transient fuel behavior (ERUDITE) is described, along with methods of accessing it. Details on 40 data tests—various accident simulation tests in the Power Burst Facility at Idaho National Engineering Laboratory, reactivity-insertion accident tests in the capsule driver core at INEL, and electrically heated rod burst tests at Oak Ridge National Laboratory—are included. Comprehensive instructions are given for four Datatran modules to access the data base and to select, sort, and plot data. The contractor is Intermountain Technologies Inc. *EPRI Project Manager: R. N. Oehlberg*

Study of Damageability of Electrical Cables in Simulated Fire Environments

NP-1767 Final Report (RP1165-1-1); $3.50

This study investigated the damage processes affecting electrical cables in various thermal environments. Three processes—insulation-jacket degradation, ignition, and electrical integrity failure—were chosen for evaluating cable damage potential, and critical flux and critical energy parameters were derived for each. Auto- and piloted-ignition fire risks were simulated. Also, hydrogen chloride generation from chlorine-containing cables was recorded. The contractor is Factory Mutual Research Corp. *EPRI Project Manager: R. E. Swanson*

LWR Core Materials Performance Program: Progress in 1979–1980

NP-1770-SR Special Report; $4.50

This report describes the progress made in 1979 and 1980 by EPRI's LWR Core Materials Performance Program, which consists of 22 active projects designed to improve core component reliability and thus to increase availability and capacity factors. Performance monitoring, evaluation of improved designs, forecasting and control of performance, and research plans for 1981 and 1982 are discussed. *EPRI Project Managers: David Franklin, Howard Ocken, S. T. Oldberg, and J. T. A. Roberts*

Fission Energy Release for 16 Fissioning Nuclides

NP-1771 Final Report (RP1074-1); $2.75

This report describes results of a study of fission energy releases and the components of this energy. Energy releases for primary isotopes, for which relatively good experimental quantities exist, were determined by a combination of mass-defect systematics and least-squares fits with the experimental data. Only the systematic study was carried out for the remaining isotopes. The contractor is Stanford University. *EPRI Project Manager: Odelli Ozer*

Modeling of Cooling-Water Inleakage Effects in PWR Steam Generators

NP-1786 Topical Report (RP404-1); $4.50

This report describes an analytic model for predicting the effect of condenser-cooling-water inleakage on the corrosion rate of carbon steel support plates in PWR steam generators. The modeling results can be used to develop preliminary estimates of the effects of blowdown water quality on denting at operating plants. Future model improvement and verification efforts, along with complementary laboratory corrosion measurement programs and improved corrosion assessment at operating plants, are discussed. The contractor is NWT Corp. *EPRI Project Manager: C. S. Welty, Jr.*

Model of Vaporous Carry-Over

NP-1787 Topical Report (RP704-1); $3.50

Details are provided on an analytic model used to predict the equilibrium chemistry of the liquid and steam phases during boiling in a once-through steam generator and during condensation in a turbine. The report discusses the model's development (including foundations, activity coefficients, and derivation of equations), implications, and applications. The contractor is NWT Corp. *EPRI Project Manager: C. S. Welty, Jr.*

Implementation of the SAM–CE Monte Carlo Benchmark Analysis Capability for Validating Nuclear Data and Reactor Design Codes

NP-1791 Interim Report (RP975-1); $3.50

This report describes processing of the reference evaluated nuclear data library (ENDF/B) for use in benchmark analysis. It discusses the implementation of the SAM–CE program, improvements in analytic methods and data processing procedures, the generation of a high-accuracy ENDF/B-V–based library consisting of 19 nuclides, and the validation of this library through detailed comparisons with other Monte Carlo codes. The contractor is the National Nuclear Data Center, Brookhaven National Laboratory. *EPRI Project Manager: Odelli Ozer*

Conference Proceedings: First International RETRAN Conference

WS-80-150 Workshop Proceedings; $28.75

This report contains 31 papers presented at the first international RETRAN conference, held in September 1980. EPRI and Energy Incorporated sponsored the meeting to provide for an exchange of information about current uses of the RETRAN computer code by utilities and other organizations. The report includes analyses of large-plant data not previously available. *EPRI Project Manager: L. J. Agee*

Patents

Each issue of the *Journal* includes a list of newly filed patent applications. The EPRI identification number, title, and abstract filed with the application are reprinted below. Information on obtaining a license under EPRI patent or patent application can be obtained from the Manager, Patents and Licensing, P.O. Box 10412, Palo Alto, California 94303; (415) 855-2866.

Information on other licensable inventions, as well as computer codes available from EPRI, is published quarterly in the *EPRI Guide*. This publication can be obtained from Research Reports Center, P.O. Box 50490, Palo Alto, California 94303; (415) 965-4081.

Cable-reaming apparatus and method
KD1287-01-02

The technique for replacing an existing underground cable and a specific apparatus for doing so are disclosed herein. The apparatus includes a main body, or cable follower, which is interconnected with the cable to be replaced for slidable movement along the latter. At the same time, the apparatus provides means for reaming around the cable, preferably by means of one or more fluid jets. Once the soil surrounding the cable has been loosened by using this apparatus, the cable can be easily pulled out of the ground. At the same time, the replacement cable can be attached to the existing cable and pulled into its place.

Method of making a transformer or like core from amorphous metal strip
KD1290-02-12

A method of making a magnetic core from amorphous strip material for use in a transformer or like electrical induction apparatus is disclosed herein. In accordance with this method, a continuous strip of nonannealed amorphous metal is wound around a mandrel to form an initially round core, which is clamped in a predetermined way and cut entirely through one transverse section while a rust-inhibiting liquid coolant is applied thereto. This provides a plurality of connected strips, which are thereafter separated into a number of groups and assembled together in a predetermined way to form a substantially oval-shaped core. This latter core is formed into final shape and thereafter annealed and simultaneously subjected to a magnetic field of predetermined strength in preparation for receiving an associated electric coil or coils.

Descaling process
KD1329-01-01

A process for the removal of deposits consisting essentially of the oxides of one or more transition metals from a surface, which process comprises contacting the said surface at a pH below 7.0 with a reagent comprising a one-electron reducing agent, which is a low oxidation state transition metal ion, in combination with a complexing agent, which is thermally stable at an operating pH. The process is particularly suitable for decontaminating the cooling system or a component associated with the cooling system of a water-cooled nuclear reactor or other contaminated plant items.

Method of and system for determining particular species of chlorine in a water sample
KD1435-01-01

A technique for determining and distinguishing between specific species of chlorine in a supply of water is disclosed herein, along with certain applicable apparatus. In carrying out this technique, one or more water samples are obtained from a larger supply and made to display a pH within a specific range. In a preferred embodiment, a sample is provided for each of the different species of chlorine to be determined. A predetermined amount of hydrogen peroxide is added to each of these samples. If hypochlorous acid and/or hypochlorite (one of the species to be determined) is present in any of the samples, the hydrogen peroxide by itself will react therewith for producing oxygen. If, however, either monochloramine or dichloramine (other chlorine species) is present, it is necessary to combine the hydrogen peroxide with a certain minimum amount of iodine, preferably in the form of potassium iodide, to produce an oxygen-evolving reaction. Dichloramine requires a greater concentration of iodine than monochloramine and, hence, the two can be distinguished from one another. In each case, the produced oxygen is detected for determining whether any or all of these chlorine species are present in the water supply and the amounts thereof.

System and method for measuring ultrasonic return signals
KD1448-05-01

An ultrasonic return signal analyzing instrument and method, including analog circuitry for making partial power measurements on two selected frequency bands of the frequency spectrum of an ultrasonic return signal waveform, and digital circuitry for measuring selected features of the envelope of the ultrasonic return signal waveform. Digital waveform measurements are converted to analog signals and then combined in an algorithmic combining circuit to produce a test statistic signal. A decision circuit receives the test statistic signal and registers a decision on a characteristic of the structure under examination, based on the value of the test statistic signal. The instrument includes a signal normalization circuit to normalize the ultrasonic return signal to a fixed peak value and includes a frequency up-converter in the normalizing circuit and frequency down-converters in the partial power measurement circuits for increasing the accuracy of peak detection in the normalizing circuit and envelope detection for the partial power band signals and the total power signal. The digital waveform feature measurement circuitry includes circuitry for measuring the rise time and duration time of the ultrasonic return signal envelope, and logic is provided for handling two distinct return signal waveforms, with rise time and duration time measurements being accomplished on the highest distinct pulse within the gate signal window of the instrument. A gate signal generated from the delayed gate input of the pulser receiver of an ultrasonic instrument is utilized to gate the various measurement functions so that measurements will be made only on the selected segment of the ultrasonic return signal waveform desired to be analyzed. A fisher linear discriminant function is used as the algorithm in connection with analyzing ultrasonic return signals from stainless steel pipe having possible intergranular stress corrosion cracking conditions therein.

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