Heat Pumps for All Seasons

E L E C T R I C   P O W E R   R E S E A R C H   I N S T I T U T E

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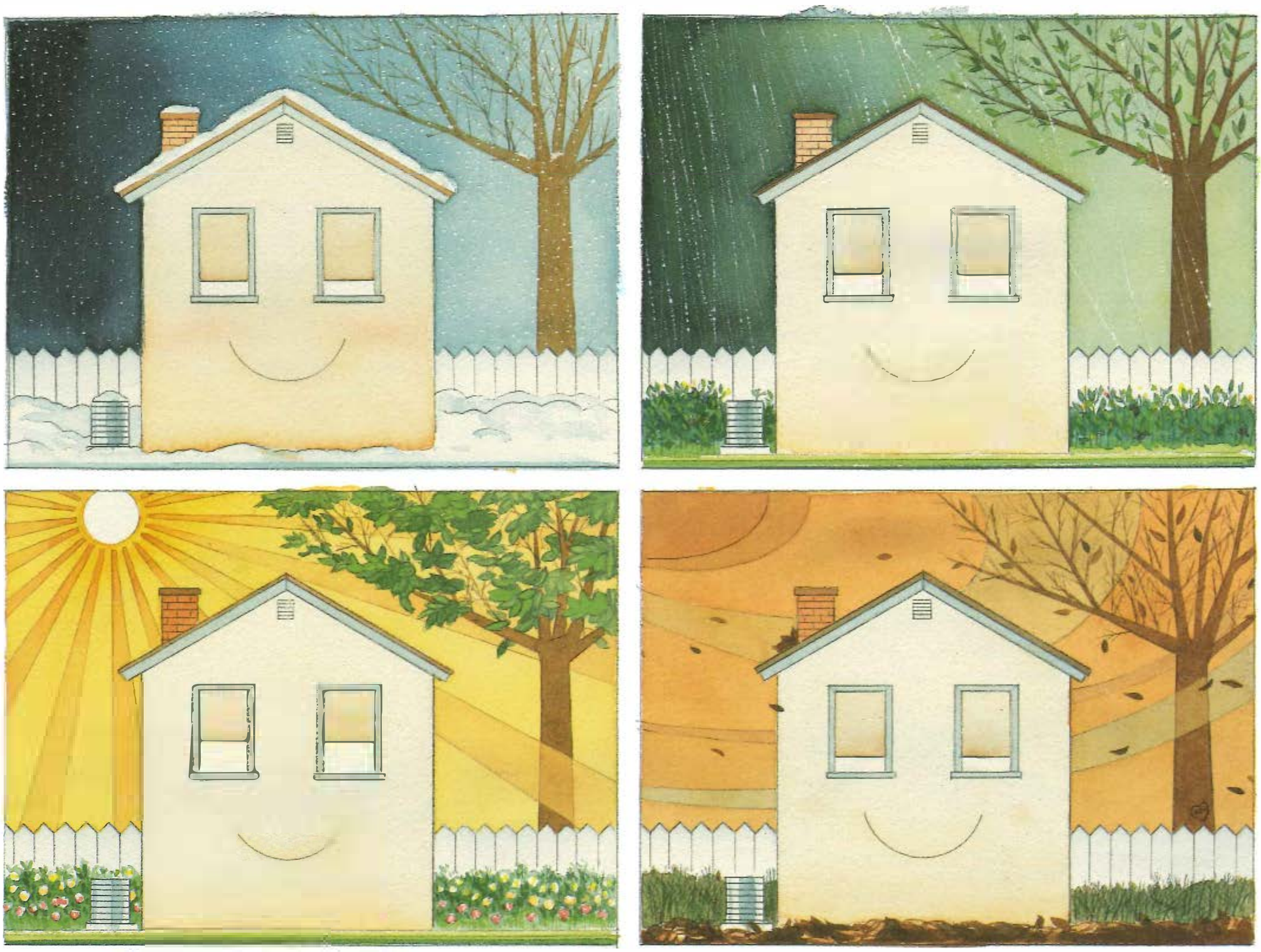

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Cover: The advanced heat pump is truly a technology for all seasons, providing both heating and air conditioning from one efficient system.

EDITORIAL

The Heat Pump: Amplifying Energy in the Home

The electric heat pump is a very exciting technology that offers tremendous benefits to consumers and society in general. Misnamed and often misunderstood, heat pumps—through the use of a small amount of electricity—are able to obtain large amounts of heating or cooling energy from the environment; often, this environmental energy is solar energy. Thus, heat pumps are essentially energy amplifiers—from one unit of electric energy they can produce three to five times as much useful heating and cooling energy, depending on the application. In effect, heat pumps behave as though they were 300 to 500% efficient.

This unique technology offers many benefits to consumers. Low heating and cooling costs, year-round comfort control from one appliance, and versatile use. For society, heat pumps offer a means to significantly reduce oil and gas use, thereby reducing foreign imports of these energy sources.

Because of the magnitude of benefits that heat pumps can provide, EPRI has focused on several activities to further improve the efficiency, reliability, versatility, and comfort of heat pumps for a wide range of residential, commercial, and industrial applications.

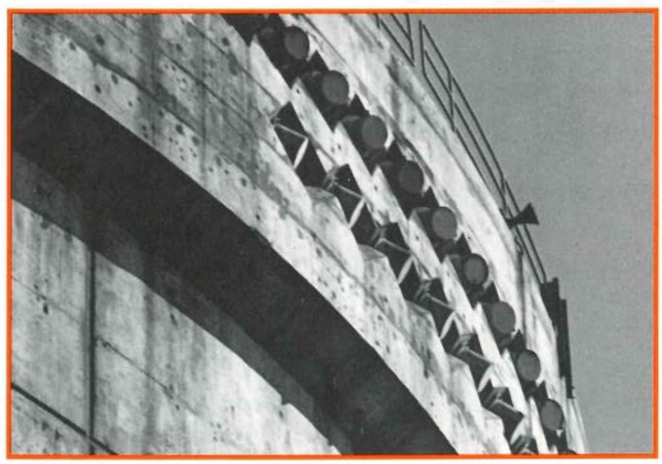
EPRI's largest heat pump activity has involved a joint effort with Carrier Corp., the company that invented practical air conditioning at the turn of the century and today manufactures a full line of home and commercial heating, ventilating, and air conditioning equipment. That effort has been fruitful: Next year EPRI and Carrier will introduce an advanced, air-source heat pump that features over 30% better efficiency than existing models. As this month's cover story relates, a state-of-the-art electronic motor and microprocessor controls will make this advanced heat pump one of the most comfort-oriented and economical-to-operate models available anywhere. Carrier's exclusive design also integrates water heating into the unit, providing the owner with essentially free hot water much of the year as a spin-off from the cooling cycle.

The advanced heat pump is the most important R&D product yet to emerge from EPRI's energy utilization initiatives that is aimed directly at the consumer market; we are proud of the success achieved at Carrier in developing and proving the technology that has gone into it. And we are equally excited about the new standard for HVAC efficiency the product will establish in the competitive market for consumer comfort.

Arnold Fickett

Arnold Fickett, Director
Energy Utilization Department

RESEARCH UPDATE



DEPARTMENTS

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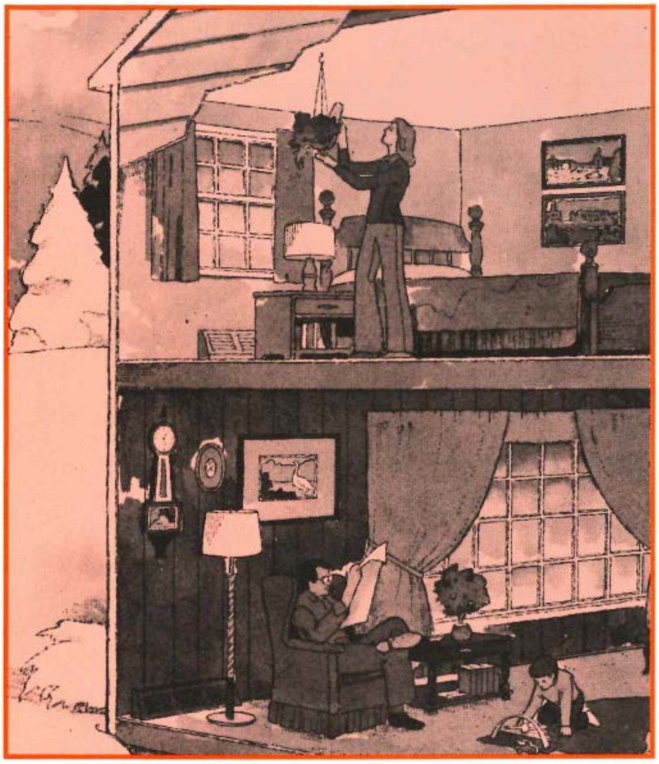
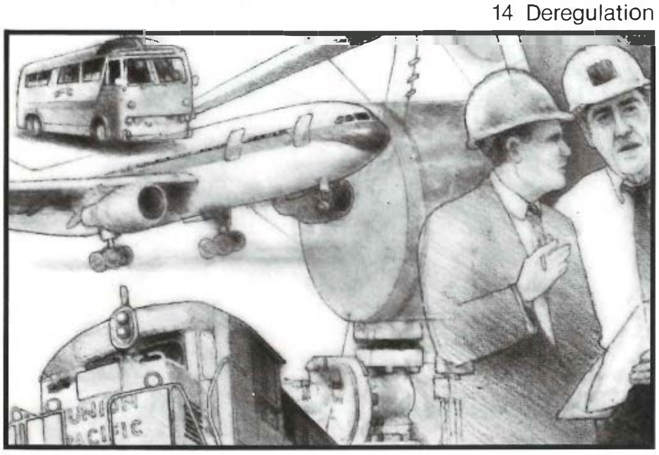
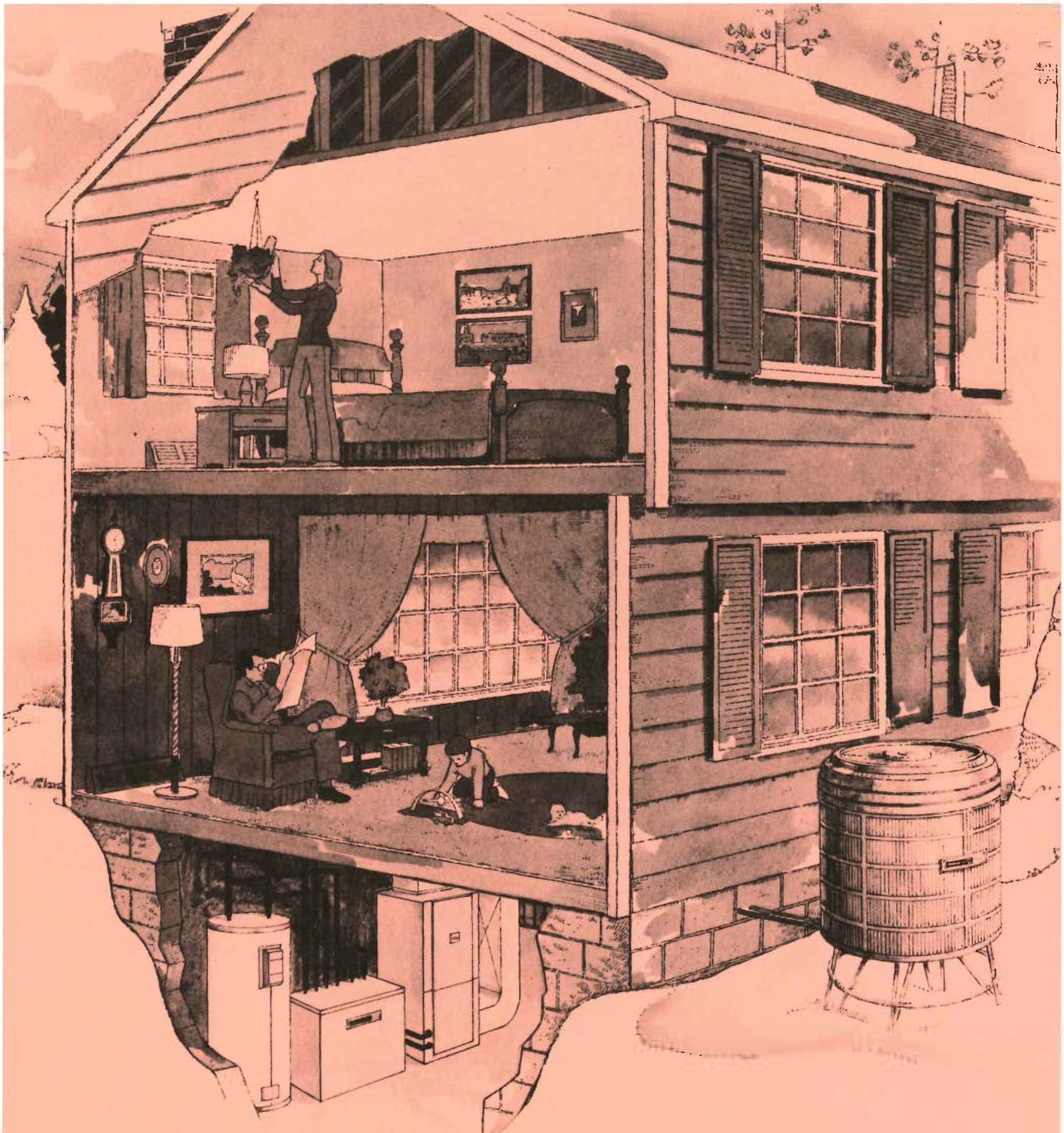


4 Advanced Heat Pump

14 Deregulation





Heat in winter, air conditioning in summer, and a big chunk of your water heating as a bonus. The electronically controlled advanced heat pump does it all, with top comfort and convenience and 30–40% higher efficiency than conventional units.

THE ADVANCED HEAT PUMP

All the Comforts of Home ...and Then Some

Willis Carrier introduced modern air conditioning to the world in 1902 when he built a machine to blow cool air through a Brooklyn printing plant that was having trouble getting inks to register because of high summer humidity. Today, engineers at the sprawling manufacturing complex he later built in Syracuse, New York, are gearing up to introduce another first in indoor climate control.

The result of over five years of joint funding and development by EPRI and the country's leading air conditioner manufacturer, an advanced Carrier Corp. heat pump, expected to be on the market next year, offers heating as well as cooling energy efficiencies 30–40% better than the average model achieves today. And because it integrates water heating with space heating and cooling, owners will pay substantially less for year-round hot water usage than they would by using standard electric heaters.

"The EPRI–Carrier heat pump represents the most significant improvement in heat pumps in years," says Arvo Lannus, manager of residential and commercial programs in EPRI's Energy Management and Utilization Division. "It's the first new thing in a technology that really hasn't changed much since heat pumps came on the scene in the late 1950s."

Already widely acknowledged to be the most efficient means available for electric space heating and cooling, heat pumps are the technology of choice for nearly a third of all new homes built each year, as well as a growing number of new commercial buildings. At the same time, marketplace pressures to reduce the cost of water heating are increasing. But heat pump water heaters that do just that have not found wide consumer acceptance. The EPRI–Carrier advanced heat pump goes a step further, integrating water heating with space heating and cooling in a package suitable for new construction and retrofit alike.

In addition to its greater efficiency and integrated operation, the advanced heat pump offers solutions to several drawbacks that have limited the acceptance of conventional units in colder climates. For example, its variable-speed compressor and fan motors eliminate the blast of cool air when the unit starts up on cold winter days, a common complaint from owners of conventional heat pumps.

The new heat pump is markedly quieter, too, both indoors and out. Carrier has designed and packaged the unit for minimal vibration and air turbulence. For example, the outdoor unit, often a source of complaints from neighbors, is only about one-eighth as noisy as a standard unit. The indoor unit containing the compressor is also extremely quiet. "People usually have to put their hands on the compressor box just to make sure it's running," says Lannus. "It's as quiet as the average refrigerator."

Microelectronic controls are key to the advanced heat pump's integrated operation. They feature a programmable thermostat for push-button night and morning comfort settings. They also provide an entree for utilities to implement load management programs, limiting the unit's overall electricity consumption at times of peak demand. Even when not demand-limited, the EPRI–Carrier heat pump requires 40–60% less power per ton of heating or cooling than last year's industry-average models.

Despite its many improvements over

current designs, the advanced heat pump won't be for everyone, however. With an installed cost for single-family homes expected to be roughly 50% more than standard models, EPRI and Carrier are hoping to carve a sizable niche in the high end of the market, rather than sweep it by storm. But if utilities extend coverage to the unit under their popular rebate programs for energy-efficient appliances, developers are predicting a bright future indeed for what they call the best heat pump made in America.

Consumer features

Installed, the advanced heat pump does not look much different than many of the over three million heat pumps already in service around the country. An enclosed outdoor fan coil of the latest Carrier design either rejects heat from inside the home to the atmosphere in the cooling mode, or collects and concentrates heat from the outside air to warm the house during winter months.

Inside the home, in the basement, garage, or even the attic, a compressor unit quietly keeps refrigerant flowing through the system and contains most of the unit's electronic controls, as well as a special refrigerant-to-water heat exchanger and plumbing connections to a water heater. An indoor fan coil connects to ductwork that circulates either warm or cool air throughout the house.

Remove the coverings on the indoor components and the resemblance to conventional heat pumps diminishes. The compressor, produced by Carrier's Carlyle Compressor Division, incorporates a General Electric electronically commutated, permanent-magnet motor drive, an industry first and the key to high-efficiency variable-speed operation. A unique rectifier circuit converts ac power into three-phase dc pulses (synthesized ac) that permit the compressor to operate at nearly any speed needed to match the cooling or heating load.

Benefits for Customers and Utilities

Carrier's advanced heat pump offers a wealth of benefits to consumers in terms of comfort and economy, as well as strategic value to utilities in demand-side management and load building.

CONSUMER FEATURES

Improved Comfort

- Gradual startup eliminates "cold blow" in winter weather.
- Microelectronic controls designed to keep indoor temperatures within 1°F of desired level.
- Better dehumidification in cooling mode than conventional heat pumps or air conditioning, even at low speed.
- Compatible with multizone space conditioning for selective room heating and cooling.

Economical Operation

- Energy efficiency 30–40% better than industry-average heat pumps. SEER cooling efficiency rating: 12. HSPF heating efficiency: 9. If economy of integrated water heating were included, efficiency ratings would be higher.
- Substantial energy cost savings projected for most climates compared with separate gas or electric resistance space heating, electric air conditioning, and gas or electric water heating.
- Free hot water during warm months as spinoff from heat rejected in cooling mode; reduced supplemental water heating on all but the coldest days.

Low Noise

- Sound shielding makes indoor compressor noise only a fraction of that of a standard heat pump; outdoor fan coil also designed for quiet operation.

Programmable Controls

- Software-driven microprocessor for integrated operation.
- Digital thermostat and push-button controls for consumer ease of operation and service diagnosis.

Service and Support

- Carrier-trained technicians for installation and service available through extensive dealer-distributor network.

UTILITY FEATURES

Reduced Peak Demand

- Requires 40–60% less power per ton of heating or cooling capacity than conventional heat pumps or air conditioners with electric water heaters.

Demand-Side Management

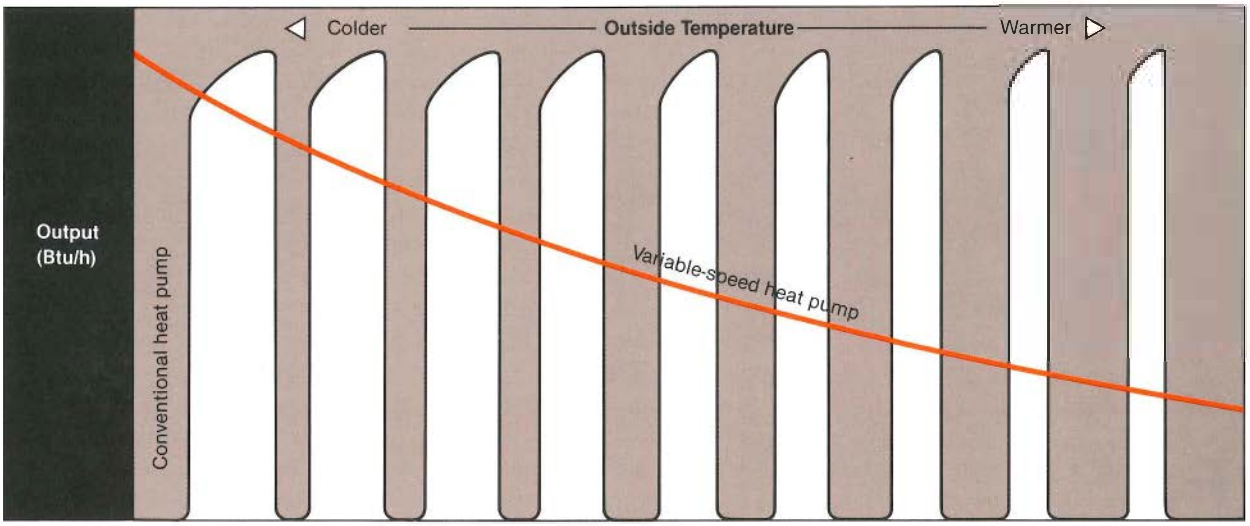
- In cooperation with customers, utilities can signal additional, automatic power demand reduction at peak periods.
- Variable-speed operation spreads load evenly over daily cycles for better load factor.

Load Building

- Applies electricity to the three largest uses of energy in the home, providing utilities a competitive alternative for increasing kWh revenues without adding to peak demand.
- Extends geographic range of heat pump appeal to colder northern climates.
- To be available in 2-, 3-, and 5-ton capacities. Marketable for small commercial buildings as well as residences.

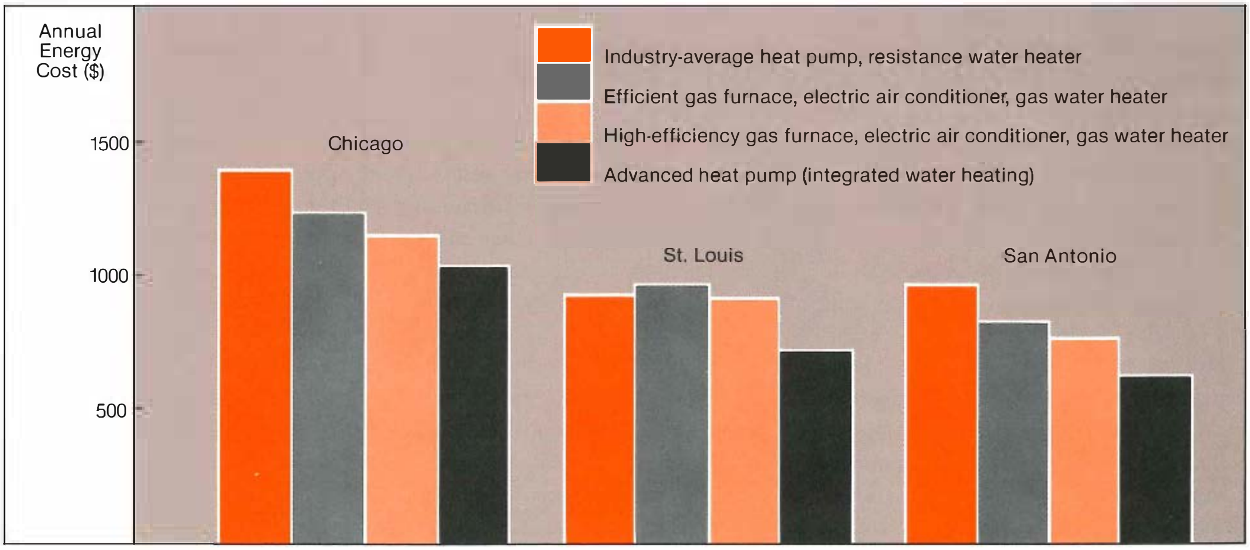
Variable Speed for High Efficiency

A conventional heat pump or furnace that operates at only one speed must continually cycle off and on to maintain a comfortable indoor temperature. For heating in cold temperatures, the unit cycles on frequently and remains on for a long part of each cycle; the on-cycles are shorter and less frequent in milder weather, but the unit still must run at full capacity whenever it is on. In contrast, the advanced heat pump's electronic compressor continuously varies its speed to closely match a home's heating or cooling load, offering substantially better energy efficiency.

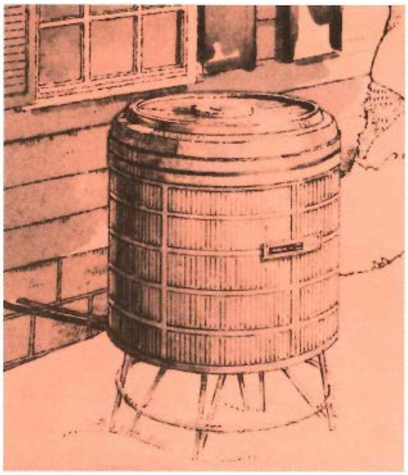


Operating Costs: How the Competition Stacks Up

Depending on the climate, the advanced heat pump with integrated water heating is expected to offer annual energy cost savings of 30–40% compared with the industry-average heat pump and separate electric resistance water heating. Performance analyses conducted by Carrier show the economy of the advanced heat pump compared with other heat pump or gas furnace alternatives in climates as varied as Chicago, St. Louis, and San Antonio.



Homeowner-Tested for Reliability



For over a year now, eight families throughout the country have been experiencing a new level of comfort and economy as they host early prototypes of the EPRI–Carrier advanced heat pump. Their contribution in helping Carrier refine and perfect a new system for home heating, cooling, and water heating cannot be overstated, for they have willingly endured the minor problems and inconveniences that attend any new HVAC product of such innovative design. The number of test units is being expanded this year to 37. All are heavily instrumented, with daily monitoring data transmitted automatically by modem to Carrier in Syracuse, New York, for performance analysis.

The William Seacrist family of four in Canal Winchester, Ohio, can claim a special distinction: they were the first to have one of the new heat pumps installed. Seacrist, a computer programmer with South Central Power Co., a rural electric cooperative in Ohio, says he has noticed a real difference with the advanced heat pump compared with the conventional model it replaced. "The air that comes out when it first turns on is actually warm, and that really makes a big difference in comfort. It's also a lot quieter. When the old one would kick in, it really came on full speed. This one sneaks up on you; sometimes it's hard to tell it's running. My neighbor likes it, too, because the outdoor fan coil makes hardly any noise at all."

Seacrist says colleagues approached him about hosting the test unit when one of them heard of his monthly heating bill. "I used to average over $200 a month in the winter and last year I used kerosene heaters as a supplement. This new heat pump costs me about $50 a month less to operate."

Bernard Woller, an official of Buckeye Power who is supervising the Seacrist test installation, notes, "There have been a few problems, as expected, but overall we're very pleased with the unit's performance. We know the homeowner is happy with it. Being able to reduce hot water costs is a real plus for utilities because that is a significant part of the consumer's monthly bill. I think utilities will want to promote that aspect, because if we can introduce electric heating and cooling, it's much easier to also gain the water heating load with this unit, and vice versa."

Seacrist has tracked detailed heating cost data on his home computer since long before the new heat pump was installed. For his patience and diligence, his prototype model will eventually be replaced with a production version at no cost at the end of this year. He adds that if he again finds himself in the HVAC market, knowing what he knows of the advanced heat pump's comfort and economy, "I'd sure ask for one of these." □

The advanced design makes the compressor motor among the most efficient in use anywhere today. The compressor itself was designed to reduce refrigerant flow and pressure losses to an absolute minimum to achieve the high system efficiencies.

Not only does variable-speed operation translate to energy savings for consumers, it also means improved comfort. In a conventional heat pump that operates at only one or two speeds, cool air is pumped until the fan coils warm up on winter mornings, or warm air may come from the registers until enough heat is rejected on hot summer days. The EPRI–Carrier heat pump starts gradually to deliver warmer or cooler air more quickly than conventional units.

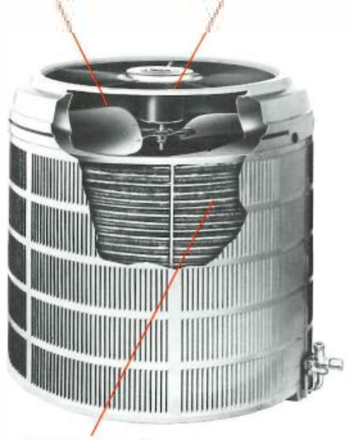
Variable-speed also means better humidity control than obtained with typical heat pumps or heating and cooling systems that always run at full speed. When cooling is done at low speeds, moisture has a better chance to collect on the indoor coil and drip off.

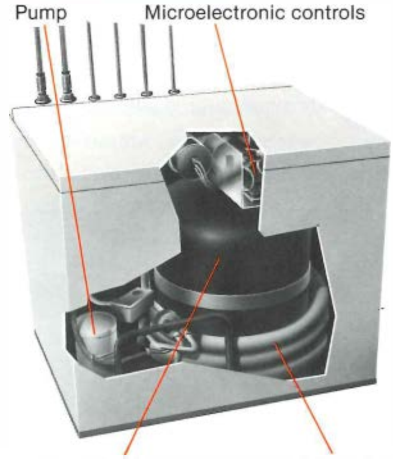
Inside the unit's electronic controls are a microprocessor and a memory chip programmed with sophisticated operating software developed and refined by Carrier over several years. Temperature and pressure sensors at numerous points in the system, plus homeowner input from one or more digital thermostats in living areas, tell the unit how it should be operating and when to reduce or increase speed.

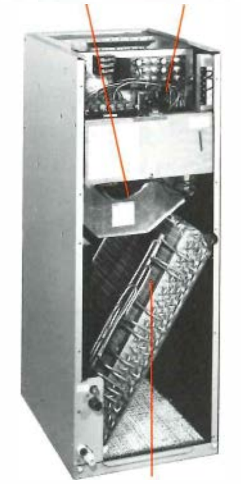
The advanced heat pump is compatible with Carrier's Home Zone system of motorized dampers and multiple thermostats in living areas for maintaining varying degrees of heating or cooling in different parts of the home. It can also be configured to operate with an existing gas furnace, using either the furnace or the electric heat pump for heating, depending on the user's choice or on current energy costs.

The precise control afforded by the marriage of electronics and variable-

A Look Inside the Carrier Advanced Heat Pump





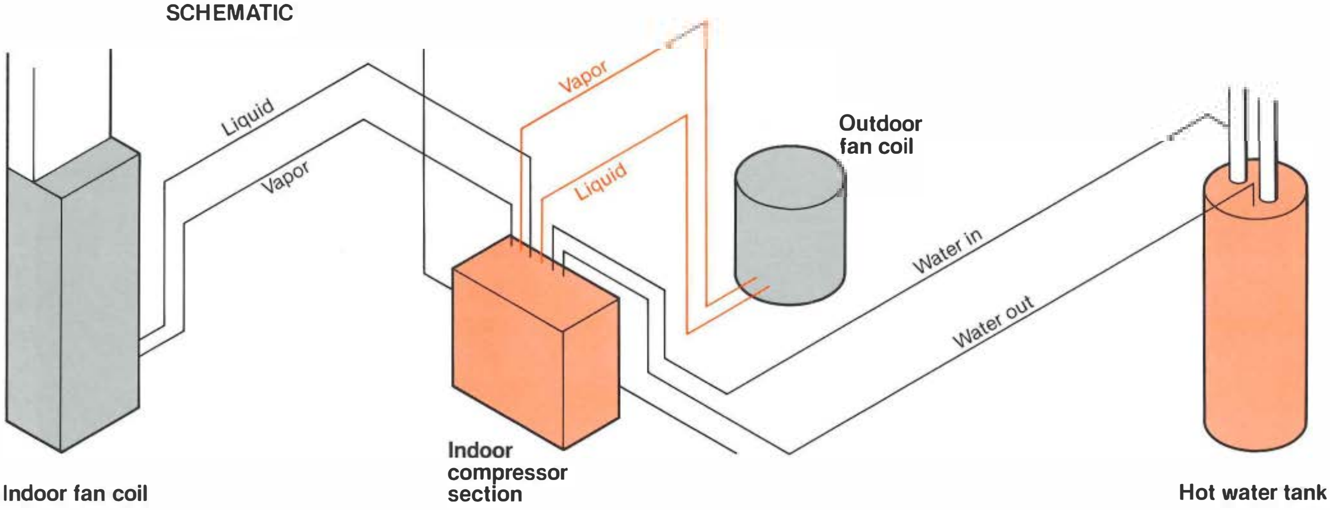


The outdoor fan coil section is simply a high-efficiency refrigerant coil with a fan and motor in a painted, galvanized steel cabinet. (The final design will have a rectangular rather than cylindrical shape.) Its function is to transfer heat from the refrigerant to outside air in the cooling mode or to warm the coil with low-temperature heat from the outside for heating the home. The outdoor section will be rated as one of the quietest in the industry.

The compressor section contains the unit's electronics and microprocessor, as well as a high-efficiency, variable-speed compressor, a refrigerant-to-water heat exchanger, and a small pump. The compressor and its motor are surrounded by a sound shield for low noise. In the cooling mode, the advanced heat pump will use some of the heat rejected from the home interior to meet most of the hot water requirements. Electronic controls will switch on a conventional resistance element in the water tank when most of the unit's capacity is required for space heating.

The indoor fan coil section connects to the house ductwork. A variable-speed fan, electronically linked to the compressor, increases or decreases speed to match the heating or cooling load. Refrigerant circulating in the coil either heats the indoor air in the heating mode or cools and dehumidifies the air in the cooling mode. Supplemental gas or electric resistance heat is switched on when the compressor reaches maximum speed.

SCHEMATIC



Product Development and Testing: Carrier at Work

Carrier engineers are picking up the pace as they put the finishing touches on what will be the most advanced heat pump ever made. At the company's Syracuse, New York, headquarters complex, a breadboard setup of the advanced heat pump has been used to develop and refine operating software contained in the system's microelectronic controls. Nearby, engineers monitor daily transmissions of performance data from prototype field test units around the country. Like all Carrier heating and air conditioning products, the new system is being subjected to rigorous cycling tests for reliability. When it goes into commercial production late this year, the advanced heat pump will be manufactured at Carrier's factory in Collierville, Tennessee.

Breadboard testing of operating software

Computer monitoring of field tests

Production line run testing

Reliability testing laboratory

speed motor drive are expected to keep indoor temperatures within one degree (Fahrenheit) of the desired comfort level at all times. The electronic thermostat also permits homeowners to program automatic night and morning temperature settings to increase energy saving and comfort control. The microprocessor that interacts with the thermostat even contains a degree of diagnostic capability to tell a homeowner or a service technician of a problem and its nature.

Thanks to a unique refrigerant-to-water heat exchanger, the advanced heat pump can supply most of a home's hot water from waste heat in the summer. On the coldest winter days, when the unit's full capacity is required for space heating, a sensor will switch on a conventional resistance element in the water tank. When neither cooling nor heating is required but hot water is, the heat pump runs at an efficiency-optimized speed without the indoor fan coil to maintain water temperature with low energy use.

Standard industry efficiency ratings for the unit are impressive, but they don't tell the whole story because they do not reflect the added efficiency of water heating or variable-speed operation. The unit's heating season performance factor (HSPF) is 9.0, 30% more efficient than the average heat pump last year. An HSPF of 9.0 means 9000 Btu of heat are delivered for every kWh of electricity. In cooling, the heat pump's seasonal energy efficiency ratio (SEER) is 12, also 30% better than average, delivering 12,000 Btu of cooling for each kWh.

Lannus says that if water heating were accounted for in the government-established method for calculating cooling efficiency, the advanced heat pump's SEER of 12 would be equivalent to about 16. In addition, the standard ratings do not reflect indoor humidity levels, expected to be more comfortable because the heat pump's variable-speed capability will remove more moisture from the indoor air. A humidifier can easily be integrated with the heat pump if needed during winter operation.

Carrier's studies indicate the operating cost saving with the advanced heat pump can be as much as 47%, compared with separate conventional gas furnace or electric baseboard heating, electric resistance water heating, and air conditioning. Performance analyses for climates as varied as Chicago, St. Louis, and San Antonio show it beating the competition across the board, with yearly operating costs of only $700 to $1000.

Benefits for utilities, too

Besides efficiencies and consumer features that place it far ahead of the competition, the EPRI–Carrier heat pump is expected to appeal to utilities on several fronts. For example, the unit is an ideal product for building customer load because it accomplishes all three of the major uses of energy in the home—space heating and cooling, and water heating—with electricity. Yet it does all this with 40–60% less demand for power than do conventional heat pumps, air conditioners, and water heaters because of its variable-speed operation. In addition, the load is spread more evenly over daily cycles, offering improved load factors from a utility perspective.

The advanced heat pump has also been designed for easy implementation of utility load management options. At times of peak demand for power, particularly on the hottest days, when most air conditioners are running full bore, a radio or powerline signal from the utility can automatically limit the power consumption of the advanced heat pump, with little or no noticeable change in comfort. Utilities are increasingly turning to load management strategies in cooperation with customers to smooth out daily peaks in power demand.

Given the competition between electric and gas space heating systems, plus the growing demand for air conditioning across the country, the EPRI–Carrier heat pump is ready-made to be the product of the future for electric utilities. Increasingly over the years, heat pumps have been the consumer choice in moderate climates such as in the Sunbelt states, where population is growing. But the significantly greater efficiency of the EPRI–Carrier advanced heat pump is expected to make it equally appealing to consumers in the colder northern states, where conventional heat pumps have been less attractive than other heating systems.

Electric space heating has grown to account for 50% of all new single-family homes and an even greater share of multifamily dwellings. "If you look at the product that has really carried the ball for electric heating, it's the heat pump," says Lannus. "So, given the nearly universal demand for air conditioning, utilities are going to get the home cooling load whether they want it or not, and it's not typically a good load for utilities. It has high peak demand, and its use is very sensitive to energy costs during moderate weather.

"In most parts of the country, the annual heating hours with a heat pump will be more than the annual cooling hours, so there are a lot of advantages to utilities the more air conditioner sales they can turn into heat pump sales," Lannus explains.

Doing that with what is considered the state of the art in heat pump technology will very likely require utilities to offer special incentives to purchasers. With a 50% higher-than-average initial cost, consumer payback from energy savings with the advanced heat pump will be four or five years. "But if you take into account a $350 rebate, that could bring the payback period down to two years for most areas, making it immediately competitive with an advanced gas furnace or with gas water heating," says Lannus.

Officials at two utilities hosting prototype test units in their service areas agree that the EPRI–Carrier heat pump could become a preferred product for utility promotion. "We're very much looking forward to mass production," says Bernard Woller, director of facilities and special projects for Buckeye Power, the power supplier for 28 rural electric cooperatives in Ohio.

"We see the advanced heat pump as our best competition against gas in this area. It is difficult to compete today by offering existing heat pump technology because it doesn't fully meet consumer needs. But with hot water, variable-speed operation, and elimination of cold blasts, we think the advanced heat pump will be a good piece of equipment to help us compete against any type of HVAC (heating, ventilation, and air conditioning) system on the market," adds Woller. He says Buckeye Power now offers three types of incentive programs for add-on heat pumps and will very likely extend those to the advanced unit if customers agree to participate in the load management option.

James Sugden, residential marketing coordinator for Boston Edison, says the new heat pump could play a key role in his utility's conservation and load management programs. "I consider it one of the best conservation options we will have in the HVAC area. When you have a new product that incorporates technologic breakthroughs and the levels of efficiency the advanced heat pump is achieving, it will make our job a lot easier. We'll be spreading the word about this heat pump not only to the public but also to our regulators. We expect it to change the way they think about heat pumps."

The view from Carrier

At Carrier headquarters in Syracuse, the pace is quickening as the advanced heat pump approaches the manufacturing production stage. Harry Hale, director of engineering services, says those involved with the project are excited because it will again place Carrier as the unparalleled leader in HVAC technology. "People are going to look at it and say it seems simple, but it represents a substantial effort in technology development, design, and innovation to make it that simple.

"We're excited about it because it will bring us back into a segment of the business—water heating—that we've been out of for a few years. It brings us back, not in the traditional way but with something that is better, more cost-effective, and more efficient, and with not just the customer but the utility in mind," says Hale.

Charles Bullock, a project leader who has been involved with the advanced heat pump from the earliest feasibility studies, says it was a team approach that brought the different pieces and aspects of the technology together. "We've spent at least the last full year homing in on the specifications and refining the operating software. In some ways it's the most complicated design we've ever made. It's certainly not a garden variety heat pump; we're up on the fringes of high efficiency."

The reliability of the new heat pump will be on the upper fringes, as well. The unit will be tested through 80–90 million cycles at Carrier's Syracuse plant, where it was designed, before going into production at the company's Collierville, Tennessee, factory near Memphis. Roger Voorhis, engineering program manager for the project, notes that reliability has long been the Carrier watchword. "We do all our design qualification up front here," says Voorhis, "to define the system's operating envelope. The software is designed to keep the unit out of operating modes where damage can result.

"This unit is designed for a 15-year life. Before we go into full production, we'll put a dozen or more of the units into our reliability testing laboratory and run them for millions of cycles. We believe we've got the highest-efficiency unit possible with the least amount of coil," Voorhis adds.

Three of the first prototype units have been operating in the homes of Carrier employees since the beginning of 1985. Eight others were installed across the country last year in homes selected for participation in the testing phase by utility members of EPRI's Heat Pump Users Group.

As was expected with such a new and innovative system, the early test units were not without problems. Prototype versions of the unit's electronic motor drive failed after a limited time in service. They are being replaced with a newer design that Carrier engineers are confident will meet the company's high standard for reliability.

The research and development that went into the advanced heat pump at Carrier is typical of the company's approach, according to Fred Honnold, vice president for engineering and reliability systems. "We spend more on R&D than any company in the air conditioning business," Honnold says—an investment of over $60 million a year in Carrier's North American operations. "The EPRI–Carrier heat pump is exactly the kind of product we like to invest in. It's a better quality product with new features of value to our customers that our competitors are not offering.

"Sometimes we make investments that give us only temporary differentiation because our competitors find ways to copy what we do fairly quickly. In this case, we have advanced technology, including the control software and some proprietary aspects for which we're seeking patent protection, that will make it difficult for our competitors to copy," Honnold explains. "The technology in this product is a tremendous improvement in capability. As customers begin to experience the product, we know the demand for it will grow."

Marketing is something that Carrier takes as seriously as R&D. For the advanced heat pump, Carrier is planning a full-court press, involving installation and service training for its more than 5000 dealers and 52 regional distributors, plus product literature and videos for consumers and home builders.

Peter Cann, marketing director for residential systems, says, "One of the most important aspects in introducing this product is training the installers and service technicians. We plan to sell the unit only through certified dealers, people we know understand the electronics that are in the unit, who can read the diagnostic codes and know what the lights are telling them. Sales training is also very important. We'll focus on the consumer features, but we'll also be selling the demand-limiting function, which is more of a utility feature."

Coordination of Carrier's marketing plans with efforts of EPRI's Heat Pump Users Group to spread the word among utilities began last January and will continue through the expected commercial introduction late this year. Carrier plans to produce the advanced heat pump in 2-, 3-, and 5-ton capacities. Although the advanced heat pump is designed primarily for the residential market, the 5-ton model will have the capacity for small commercial buildings. The variable-speed, integrated design is expected to eventually find its way into Carrier's larger commercial HVAC systems.

Breaking new ground

The advanced heat pump represents a first for EPRI in a couple of ways, according to Lannus. For one, it is the first product of EPRI R&D that is aimed directly at end users: homeowners and owners of apartment buildings and small commercial buildings. "The HVAC area is one where, traditionally, products are developed by manufacturers and sold to consumers, and the utilities just sell the electricity," says Lannus. "In this case, however, the product was conceived with utility input with the clear aim of developing a better heat pump with benefits for consumers and utilities alike."

It is also a first in terms of the contractual arrangements with Carrier to manufacture and market the product. Typically, EPRI-funded technology is licensed on a nonexclusive basis to manufacturers or service organizations to ensure flexibility and broad availability. But with the advanced heat pump, for which Carrier has provided a significant share of the nearly $6 million in development funding, Carrier (a United Technologies Corp. subsidiary) holds a limited exclusive license.

"Once the pump is in full production, the money that Carrier will have put into tooling for manufacture, distribution, installer training, and technical support will be many multiples of the research cost," explains Lannus. "So, they must have some protection to recover that.

"Also, an exclusive license helps hedge against reverse engineering by a competitor, giving Carrier a substantial lead to market with a product that will eventually become the industry standard and be copied by others. We had to create an attractive financial environment as an incentive to get Carrier to join us in developing this product.

"Now, after many years of effort, EPRI is going into the consumer market with a state-of-the-art heat pump that we believe will be eminently marketable," says Lannus. With it, there is as much at stake for utilities as for Carrier, perhaps even more. "Like any other major manufacturer, Carrier makes a full line of heating and cooling products, including a variety of gas-fired home heating systems. If you look at potential revenue from the sale of electricity that this heat pump will produce over its 15-year life, each unit could represent $15,000 or more to a utility. This could be 8–10 times more revenue per unit than for Carrier, which will typically get only about one-third of a unit's installed cost."

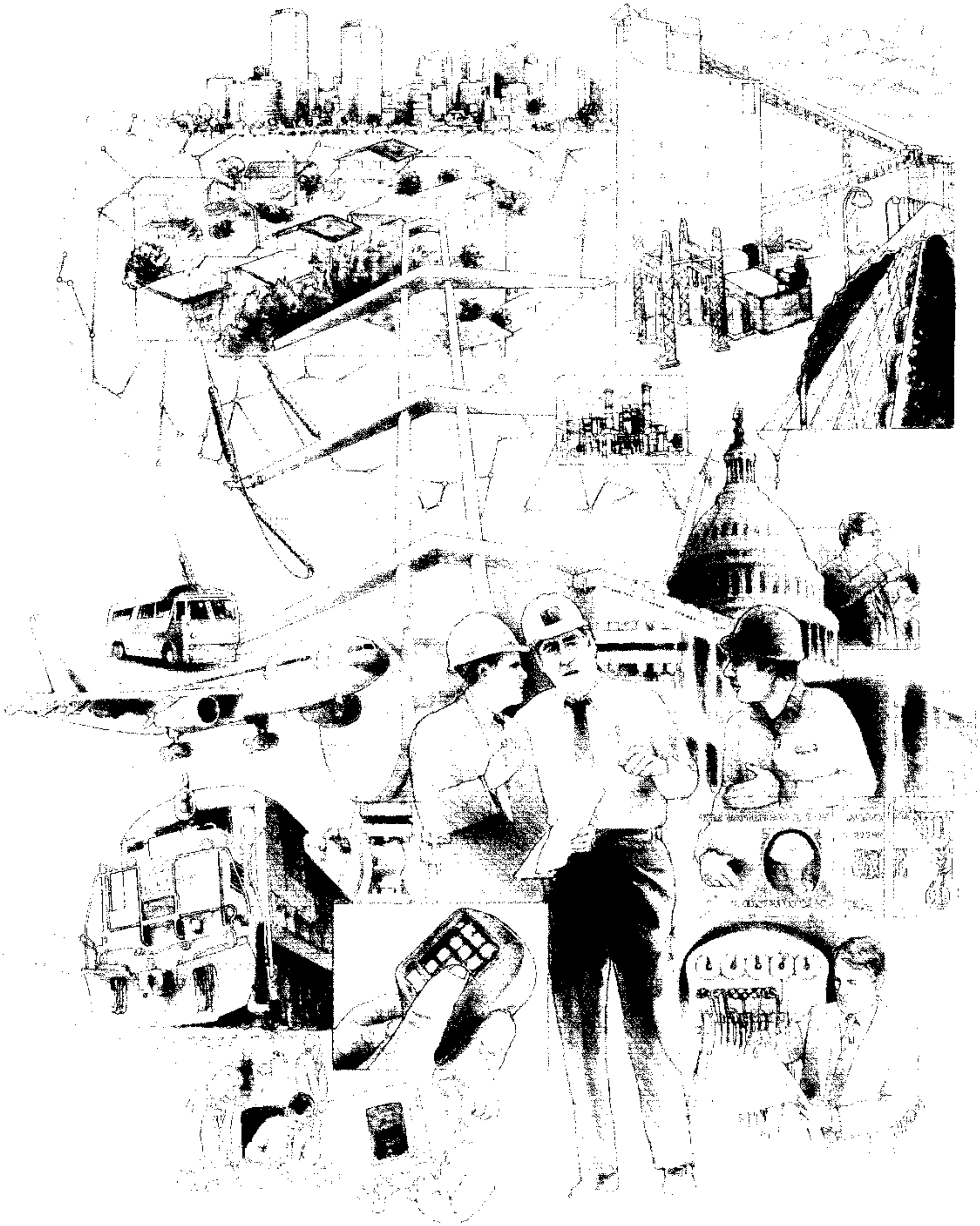
A new standard in efficiency

From EPRI's perspective, perhaps even more important than the Carrier advanced heat pump's arrival on the residential and commercial HVAC market is the new standard of efficiency it sets for the HVAC industry. "This will force other manufacturers who want to remain competitive to develop their own lines of high-efficiency heat pumps," predicts Arnold Fickett, director of EPRI's Energy Utilization Department.

"It's only going to be a matter of time before they all have equipment with this kind of capability in the field. Instead of seeing this as just the first consumer product to emerge from EPRI's end-use initiatives, which it is, I think what we've really done is play a catalytic role to accelerate the commercial availability of this advanced technology by three or four years," says Fickett.

Within a year, builders and homeowners will have a new choice when considering a purchase of HVAC equipment, one that weds state-of-the-art electronic control with a fully integrated heating, cooling, and water heating system. If they are looking for maximum comfort and minimum operating cost, the choice will be clear. For consumers, the EPRI–Carrier advanced heat pump will stand out from the crowd in economy, value, and reliability. For utilities, the system will represent for some time the preferred electric alternative in the competitive world of space heating and cooling. ■

This article was written by Taylor Moore. Technical background information was provided by Arvo Lannus, Energy Management and Utilization Division.



by Brent Barker

DEREGULATION
Facing the Big Question

Will increased competition lead to deregulation for utilities as it has in other industries? Discussion of the question at EPRI's latest Advisory Council seminar ranged from economics to technologic barriers to effects on service, but one idea surfaced again and again: It could happen here.

Airlines. Banking. Railroads. Gas. Trucking. Telecommunications. There has been enough deregulation in American industry in the last decade to suggest that the momentum might sweep through and carry with it the regulatory umbrella of the electric utility industry. Although nothing is certain, some believe this industry too is susceptible to the classic pattern of deregulation, in which market forces overwhelm the need and desire for regulation.

Certainly, the seeds of change are already germinating. Competition in the generation side is heating up; some restructuring is already occurring within the industry; and new combinations of organizations are being formed inside and outside the regulated utility world. But does increasing competition among electric suppliers necessarily lead to deregulation? Among those closest to the utility industry, skepticism abounds.

"What's happened in other industries just doesn't apply here," has been a characteristic response. "This industry is unique in terms of its obligation to serve, its capital intensiveness, and its long planning horizon to meet future demand," goes the argument. "The only people who can provide reliable service are the traditional utilities."

Outsideers often see it differently. "The writing is on the wall for the electric utility industry," says Eric Zausner, senior vice president, Booz, Allen & Hamilton. "You hear the same litany of responses—the impossibility of it all—in every industry going through the transition."

Roger Noll, professor of economics and director of public policy at Stanford University, tends to agree. "You'd better plan on deregulation in five to ten years or get rolled—it's coming like a freight train," he concludes. Ted Stern, executive vice president of energy and utility systems groups at Westinghouse Electric, is less certain that the freight train can't be derailed before it hits. "There has always been competition. What is different today is the extent of competition brought about by the lack of growth in the utility industry. If reduced growth is simply temporary, full deregulation will never occur—competitive generation will just not be available in large enough quantities to impact the existing structure."

> "In the 1970s economic regulation fell apart at the federal level because it was perceived as an overly blunt instrument creating inefficiencies. It is now starting a slow and tortuous withdrawal at the state level."
>
> *Noll*

Zausner, Noll, and Stern were three of six speakers whose remarks stimulated discussion at EPRI's most recent Advisory Council Seminar, a gathering held each year to explore key issues that could affect the Institute and its program. Some 60 individuals representing a cross section of leadership in utilities, industry, government, and academia discussed the prospects and implications of deregulation in the generation of electricity. For three days of point and counterpoint they pursued several elusive threads: whether deregulation could or would promote economic efficiency, equity among all players, adequate service reliability, and technological advance.

Those more detached from the industry tended to frame their views about the future of deregulation in terms of "will it or won't it happen," whereas those closer to the industry and to the regulatory process presented theirs in terms of "should it or shouldn't it happen." Where they found common ground was on the distribution side of the business. No one envisioned that the distribution of electricity would or could ever be completely deregulated, nor did anyone think it should be. It is the generation side of the business that has been dislodged from its half century of stasis and is now the center of debate.

Many agreed that it is getting harder and harder to make the case for generation being a natural monopoly and that it will be increasingly difficult to defend laws and regulatory practices that set different rules for different players. Several argued that economic efficiency might be better served by letting the generation side go into a fully competitive arena. But what this left was the spectre of a largely regulated distribution business and an unregulated generation business, with an uncertain cloud hanging over the linkage in between. The transmission system, several pointed out, is being overlooked and underestimated in this whole feverish debate, when it is, in fact, the linchpin of the whole system.

Driving forces

The transmission system is one of three driving forces that over the last 20 years have helped to bring the deregulation issue to a head in the electric utility industry. Widespread interconnection in the 1960s and 1970s—designed for system reliability, economy, sales, and improved operations—had an unintended result. As power was purchased and transferred among more and more utilities in a region, the lines of local autonomy began to shift. According to Noll, "interconnection began to erode the logical case for a natural monopoly. Each plant became a smaller percentage of the total system, and the whole thing began to look like a competitive retail business. Load management decisions shifted from local to regional levels."

The second driving force was a general disenchantment with economic regulation that occurred in the 1970s. "*Environmental protection*," says Noll, "stopped being a symbolic gesture in the 1970s and became a serious institutional commitment. In contrast, *economic regulation* fell apart, at least at the federal level, because it was perceived as being an overly blunt instrument that creates inefficiencies. Economic regulation is now starting a similar but slow and tortuous withdrawal at the state level."

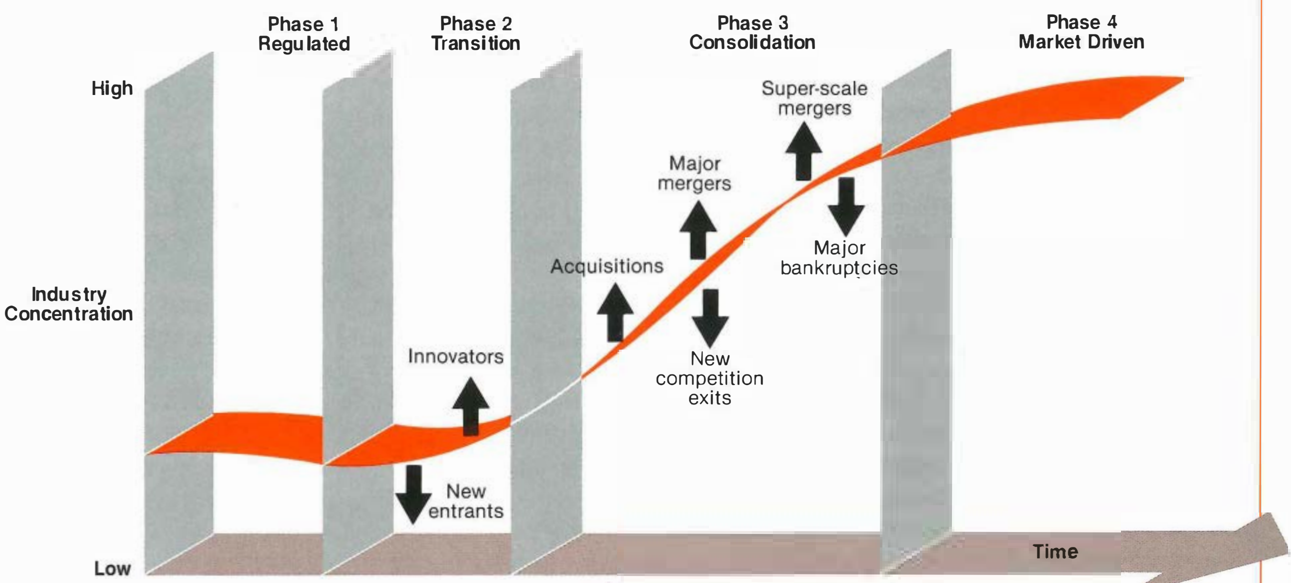
One of the pressures toward reduced economic regulation in the 1970s was the creation of the Public Utility Regulatory Policies Act (PURPA), which essentially guaranteed that independent generators could sell electricity to utilities at premium rates. PURPA provided the opening wedge for competition to enter the electric utility industry. Competition was also given a boost by some old-fashioned politics. "American politics always seeks a scapegoat in times of economic dislocation, and during the energy shocks of the 1970s, the utilities were it," says Noll. "The U.S. government froze the utilities out of R&D in decentralized technologies, funded this research in the private sector, and put a structure in place to try its experiments outside the existing industry. It put a lot of nonutility people in the energy business. This became a decentralizing force, one that ultimately distorted investment by forcing investors to consider all kinds of questions that shouldn't matter, such as 'who owns you?' and 'what kind of organizational form do you have?'"

> "Regulation sows the seeds of its own destruction. Regulation inexorably leads to a high-cost commodity, and it is high cost that becomes the basic undoing of all regulated industries."
>
> *Zausner*

A third driving force, less conspicuous but in many ways of greater impact and implication, was also gathering steam in Washington in the 1970s in the form of U.S. macroeconomic policy. As characterized by Charles Stalon of the Federal Energy Regulatory Commission, "the United States from the end of World War II had pursued a policy of low interest rates, high economic growth, and high employment. This was the engine that carried our long-term vision and long-term investment. But in the 1970s the macroeconomic policy of the United States changed. To combat inflation, the United States shifted its policy to emphasize high interest rates, slow economic growth, and high unemployment. The result of high interest rates is that we went from being an exporter of capital to an importer of capital, and forced the marketplace to think short term–short gestation projects and high returns. In many ways, the shift from low interest rates to high interest rates destroyed the natural monopoly of the capital-intensive electric industry."

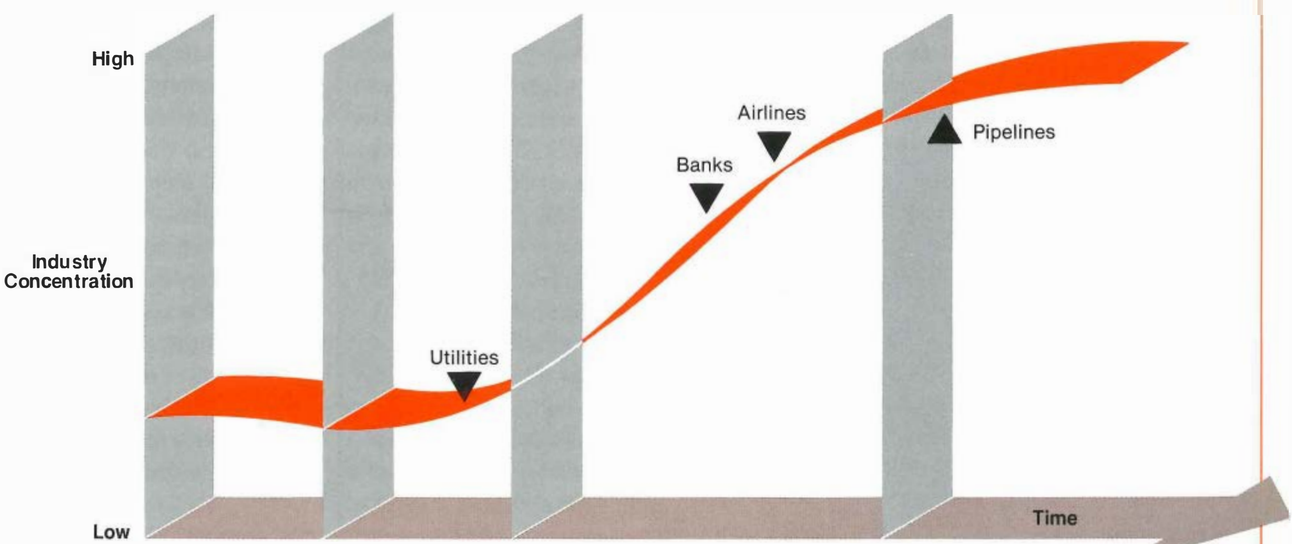
These three forces—interconnection, regulatory policy, and macroeconomic policy—all served to weaken the social contract of utility regulation. They caused some of the economic inefficien-

The Pattern of Deregulation



Source: Booz, Allen & Hamilton, Inc.

In a five-year study of deregulated industries in the United States, Booz, Allen & Hamilton found similarities in how the competitive forces play out in each industry as it moves through an evolution from regulation to free market. With new competition entering the regulated business, the number of companies initially increases. But as competition heats up, some of the new players are forced out, mergers and acquisitions occur, and industry concentration begins to increase. In the final stages, as the spread of profitability widens between winners and losers, consolidation snowballs, leading to super-scale mergers and some major bankruptcies. Eventually, concentration levels off as the industry stabilizes in a market-driven environment. Booz, Allen & Hamilton places the utility industry in the so-called transition phase.



Source: Booz, Allen & Hamilton, Inc.

cies held in place by regulation to surface, introduced some new competitive forces into the business, and helped to alter some of the fundamental economics by which competition is played out. High interest rates to an industry propelled on a destiny of large-scale construction was a watershed event, one that turned the cost curve upward and the demand curve downward.

Seeds of destruction

It is high cost that becomes the basic undoing of all regulated industries, according to Eric Zausner; and on the basis of a five-year study of deregulated industries by Booz, Allen & Hamilton, it is regulation itself that inexorably leads to a high-cost commodity. This bit of circular reality is why Zausner says that "regulation sows the seeds of its own destruction."

He points out that it is the nature of regulation—for all sorts of socially beneficial ends—to stimulate overcapacity, to create cross subsidies among various classes of customers, and to stifle competition and innovation. Products are viewed as commodities, and services are bundled. The net result is a high-cost commodity and a structure that begins to break down when innovators from within and new competitors from without begin to change the business. Price competition sets in, costs are slashed, and the business is unbundled—peeled apart into its different pieces and sold at different prices.

"If there is deregulation, we will see a Darwinian struggle among utilities for survival, and price pressures will force them to look for every quick fix to cutting costs. Research may suffer, and it will become competitive itself."

Stern

This ferment is characteristic of what Zausner describes as the "transition phase, or phase 2," of a four-part evolution from a regulated industry to a market-driven industry. Phase 2 is where he currently places the utility industry. History shows that industry concentration tends to drop at the onset of phase 2 as new competitors enter the business, find niches, and pick off some of the pieces. In airlines, for example, this was the point when we witnessed the entrance of many new regional carriers, such as Rio Airways and Air Atlanta; and a number of innovative, limited-focus airlines—niche players—such as People Express Airlines and Frontier Horizon.

Phase 3 is characterized by industry consolidation, where mergers and acquisitions snowball and some of the new entrants are forced out. This is where Zausner currently places airlines and banking. Ironically, some of the innovators that started the business changing in the first place often lose their competitive advantage at this point and drop out. People Express is a notable example. The end of phase 3 is marked by an intensification of acquisition activities, by superscale mergers, and typically, by some major bankruptcies among firms that don't move fast enough. Phase 4 is the end point—a market-driven industry, with concentration stabilized. Zausner places gas pipelines in this category.

Zausner's deregulation scenario seems to be borne out strongly by recent history. But is the trend toward dereg-

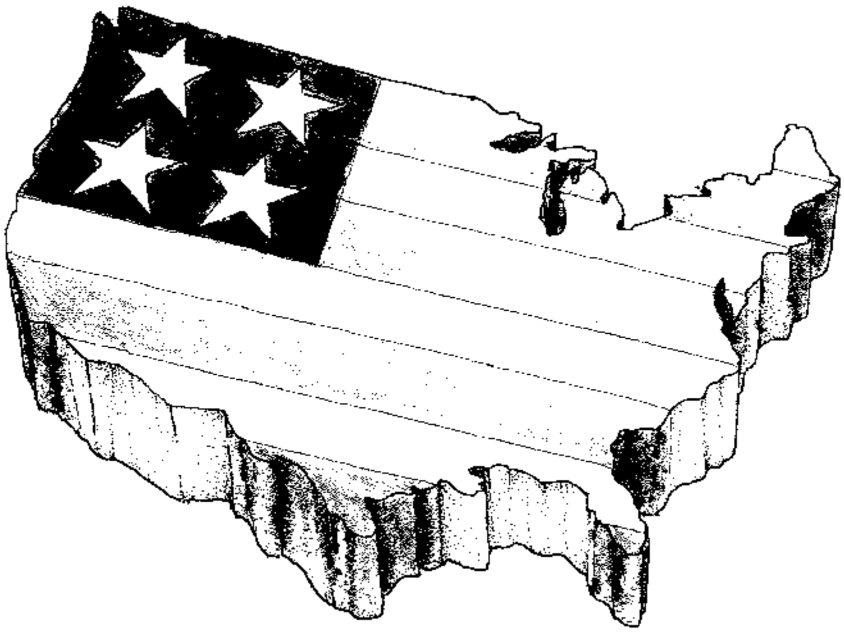
One of the challenges presented to the seminar participants was to explore the effect of new competitive forces and deregulation on the advancement of technology. Will deregulation inhibit or promote the development of improved technology? Will the role of R&D be enhanced or diminished? Can a cooperative research organization, such as EPRI, survive in a more adversarial era?

Ted Stern, executive vice president of energy and utility systems at Westinghouse, suggested that the answers to these questions could be most easily discerned by following the money trail. "From the manufacturer's point of view, the growth in the utility market is no longer there, and neither is the torrent of technology it once supported. The new markets for technology will be primarily at the lower end of the power generation scale—small, quickly built, and relatively low-cost increments. Deregulation, if it comes, will only accelerate today's trend toward combustion turbines, combined cycles, and waste-to-energy systems."

Following the money trail back to utilities, he says, "If there is deregulation, we will see a Darwinian struggle among utilities for survival, and price pressures will force them to look for every quick fix to cutting costs. Research may suffer, and it will become competitive itself. There will be less sharing of technology. EPRI could face competition from suppliers, interlopers, even technically astute utilities. The whole thing could quickly become a house of mirrors."

Stern thinks that the competitive

Impact on Technology and Centralized R&D



pursuit of individual, short-term interests will lead us "to make some technical decisions not in the best interests of the nation as a whole." He is particularly concerned that as a country we will lower our sights and relinquish our leadership in technology to nations who have made a stronger social commitment to the future. And one measure of that commitment is long-term research.

He points out that MITI in Japan, for example, will funnel more than three times EPRI's budget into long-term energy research this year. Called "Operation Sunshine," the effort will focus on such leading-edge research as solar cells, superconductivity, and IGCC technology.

"In a deregulated environment," he concludes, "EPRI's best role will dovetail with national priorities—concentrating on longer-term R&D. We are now, and permanently, engaged in global competition, and long-term research will be necessary to meet this challenge. By shifting emphasis to the long term, EPRI could become to America what MITI is to Japan."

Would utilities support such an organization? Stern doesn't think a deregulated industry could muster research of the scope and scale needed for global competition. Therefore, he envisions government support for some part of EPRI, and he sees it as quid pro quo for removing the regulatory umbrella. "What government takes away, government must provide."

Anne Carter of Brandeis University is equally apprehensive about an unregulated market's supporting cooperative R&D. "If utilities can't incorporate dues to EPRI in the rate base, where is the support going to come from? It's possible they might pool their money voluntarily. But that hasn't worked in automobiles, in shoes, in agriculture. It hasn't worked anywhere. And foreign countries haven't relied on that either. I think it's a mistake to assume that if we leave it up to the market forces, there will always be an EPRI."

Henry Linden, executive advisor and former president of the Gas Research Institute, took exception to both the threat to cooperative research and the long-term R&D focus. "Having faced deregulation in a sister industry, I'm not at all frightened by it. I see no threat to EPRI. No fundamental problem—just one of reorientation, rolling with the punches. The greatest threat would be to focus exclusively on long-range R&D. Some of the biggest enemies of R&D are those who tell you to do long-term research, and then come back and ask 'what have you done for me lately?' They'll cut you off at the knees. You've got to earn your franchise every year, and that means a portfolio of products and plenty of near-term deliverables."

Derek Davis, member of the United Kingdom's Central Electricity Generating Board, acknowledges that the majority of CEGB's $300 million per year R&D program supports current operations. "EPRI should not ignore the shorter-term operational role. As for the longer term, logic suggests that this is primarily in government's court. But I think it would be a mistake to suggest that because of government support, utilities are divesting themselves of long-term interest. Utilities will need a very big foot in the long term." □

ulation likely to continue? Does deregulation work?

Edward Burke, chairman of the Rhode Island Public Utility Commission, doesn't think so, doubting whether competition is really served in the end by deregulation. "We deregulated the bus industry, and we are now down to one national bus company, Greyhound, which has just acquired Trailways. In the telecommunication industry, as far as long-distance telephone goes, MCI is already in disarray, and the picture for GTE is not particularly good. So I fail to see where the competition has any staying power.

"I look at our deregulated airline industry," Burke continues, "and see that we now have eight companies that carry 90% of the passengers. When we complete the Piedmont–U.S. Air merger, seven will have 94% of the traffic in the United States. All we need is two or three more mergers and we will have absolutely no competition at all. So while there is transitory competition, won't we just end up with some major monopolies that are anticompetitive?"

Zausner says no: "Right now there is definite competition in the airline industry, and we have a much lower cost airline system than we did before. If and when the situation becomes anticompetitive we can deal with that through antitrust suits, not through economic regulation. As for buses, I couldn't care less if there is only one bus company. One bus company is not a natural monopoly because there is plenty of intermodal competition from both automobiles and airplanes. This is what keeps them in check, not another bus company."

But as a number of participants made clear, in the final analysis the future of deregulation may not depend on whether it promotes competition or lower costs but on whether it delivers on larger promises to the public—continued acceptable service, including safety and reliability. "I'm not persuaded there will be a lasting trend toward deregulation," says Stuart Udall, attorney at law. "I don't sense any slackening of interest by the public in the kind of protections afforded by regulation. Lack of such protection is already widely perceived in the airline industry, and I think Congress is going to get back in the airline picture within five years."

"You're going to see an increase in mergers and acquisitions. Clearly the economies are there for significant savings by combining small companies, and that's going to count in a competitive environment."

Geist

As Chauncey Starr, president emeritus of EPRI, points out, safety issues cannot be separated from economic regulation. "Safety is a variable. It can't be defined exactly. Under the economic pressure of deregulation, such intangibles as safety can easily diminish within officially acceptable limits."

Discussion at the seminar returned repeatedly to the problem of deteriorating service. One participant cited a Gallup poll that showed 75% of the public is dissatisfied with the breakup of AT&T because of the perception of poor service. Most laughed when airline service was described as an oxymoron, and occasional asides could be heard about the horrors of being stranded in one of several hub airports. The service erosion that seems to be an inevitable companion on the road to deregulation doesn't sit well. But Charles Stalon provided some useful perspective on consumer choice and drew the analogy close to home.

"Clearly, we saw that when public preferences molded the airline scheme, what we got was lower-quality service at lower prices," said Stalon. "The public made a trade-off. The question before us is how do we know that the quality of electric service is optimal? Should the government impose a quality of service on the public that the public would not pay for if it were free to make its own choices? I'll tell you what I told AT&T before the breakup. I don't wear the best clothes. I don't drive the best cars. I can't even afford the best hospitals and doctors. Why am I paying for the best telephone system in the world?"

Reliability of electric service remains extraordinarily high in the United States; it is a point of pride in the utility industry and a value assumed to be shared with customers. How much reliability would suffer under deregulation is unknown, as is the trade-off the public might make for reduced cost. But as with complaints over airline service, the real value of high reliability to customers may not become evident until service quality actually drops. The effect could be considerable. Electricity is, after all, a central, continuous part of everyday life, not an intermittent service, such as airline travel, in which delays and interruptions are more easily tolerated. Or is it? The answer would become clear with greater segmentation of the market. Some classes of customers will clearly be willing to trade lower reliability of electric service for lower prices; others will not—the loss of personal comfort and convenience or the cost to their business of an outage may be just too great.

Pathways to the future

If economics, policy, and precedent are setting the stage for deregulation, how will the industry respond? And where is it headed? Jerry Geist, chairman and president of Public Service of New Mexico, presented three possible pathways to the future and described the particular leading-edge restructuring his organization is attempting.

The first path, entitled "Back to the Future," calls for fixing the broken framework of regulation by "putting the symmetry back into the social contract." By this Geist means, "if and then. . . . If utilities have the obligation to serve, then customers have some obligation to pay. If there are going to be penalties, then there ought to be rewards. If there are rules set in advance by regulators, then regulators shouldn't be making judgments in reverse." This path calls for a return to full and equitable regulation, and Geist believes that if a vote were taken in the industry today, this path would win.

The second path, called the "Balancing Act," assumes that competition and deregulation can coexist within the same company or in the same jurisdiction. "This is really the status quo, with perhaps a little more competitive entry, some wholesale wheeling of power, maybe open access to the transmission network. It means cost-based rates for captive customers and market-based rates for contract customers. Economists regard this as an inherently unstable situation, and we see it as really just a transition path—not an option for PSNM."

The third path—and the particular choice of PSNM, given its current measure of excess capacity—is entitled by Geist "Take It or Cleave It." It separates the business into unregulated generating companies, or gencos, and regulated distribution companies, or discos. According to Geist, "Gencos are fixed assets with geographically dispersed markets, whereas discos are fixed markets with geographically dispersed generating resources."

In Geist's view, path three would entail full competitive entry for all gencos, wholesale and retail wheeling, and regulated discos with an obligation to serve and a right to shop. State regulation of discos would focus on their prudence in power purchases. The transmission system would end up operating as a common carrier, with possible antitrust oversight by the Department of Justice.

Some restructuring along these lines is already in evidence in today's competitive environment. "Independent gencos are going up all around us and in enormous ways," says Geist. "On the other side, we are seeing contract customers demanding and exercising competitive choice; they are doing it in spades in all parts of the country. I even know of some real estate developers who have organized to demand price breaks for blocks of customers."

From the utility side, some of the leading restructuring is being done by PSNM itself. Under its proposal to the state of New Mexico, it would split into a genco and a disco, with the transmission assets going to genco. Genco would be under federal regulation, with full access to interstate markets. Disco would be under state regulation, with rights to the transmission system in order to shop from competitive suppliers as it is progressively weaned from the original genco.

"There is not adequate transmission in many areas. . . . Unless the transmission problems are addressed, talking about a marketplace for deregulated generation is not only naive, but possibly dangerous."

Varley

A corollary to Geist's vision of the future, where utilities are vertically disaggregated, is the notion of horizontal consolidation. "You're going to see an increase in mergers and acquisitions," predicts Geist. "One of the reasons is just the sheer number of companies. When 17% of the companies own 61% of the generation, there is considerable room for consolidation. Certainly, the economies are there for significant savings by combining small companies, and that's going to count in a competitive environment. A company ought to generate at least 4000 MW to optimize its economies of scale."

Stalon, among others, agrees that most utilities remain suboptimal in size, largely because of market suppression by state regulatory forces, and that sooner or later restructuring is going to occur. Stalon sees two basic options for the future. The first would be the large-scale merger of investor-owned utilities (IOUs) within the current regulatory framework. "This would be a world of giants like American Electric Power—large-capacity, multistate, vertically integrated utilities. Along this line, Edward Trillio of Shearson Lehman believes we could see the consolidation of 150 IOUs into 50 large companies within five years." Stalon's second option for the future, analogous to Geist's third path, involves the separation into regulated discos and market-coordinated gencos.

Comparing the two, he says, "The merger option would shift more power to the federal government, whereas the option of vertical disaggregation and market coordination would shift more power to the market. Therefore, the principal question of the future for state PUCs is whether they prefer to lose power to the feds or to the marketplace. As for economic efficiency, it would almost certainly be better served by the market coordination option."

Nevertheless, a number of participants remained dubious about the possibility of genuine marketplace dynamics, given the physical limits of the transmission system. Andrew Varley, then chairman of the Iowa State Utilities Board, was perhaps the most vocal. "The transmission system we now have in place cannot handle the load; there is not adequate transmission capacity in many areas to take care of all potential market transactions. We would need the equivalent of a truly integrated national grid to have any semblance of a free working market. Unless the transmission problems are addressed, talking about a marketplace for deregulated generation is not only naive but possibly dangerous."

As a result, Varley's view of the future comes down to path two, the "Balancing Act." To make today's balance between competition and regulation work, he proposes several goals: proper pricing based on cost of service; removing preferential treatment for unregulated generators; providing utilities with some real incentives for cost reduction; and last, providing service variety. These goals capture his basic dictate for making the regulatory compact work: "Giving customers the quality of service they want at a price they are willing to pay."

The price must be right

Varley is concerned that many utility executives and state regulators "fail to see the limits of regulation," and therefore tend to price electricity out of the market. "Regulators have set prices to hold down costs to residential customers and passed those costs on to commercial and industrial customers, leaving many of them in noncompetitive positions. You can destroy your market that way.

"Regulators forget that they can't force a class of customers to buy at a given price. Industrials have alternatives, and they can and will leave the system to protect themselves competitively. Utilities, in turn, often fail to see the limit of how much cost can be passed through. They feel betrayed if they can't recover the cost of a new plant as it comes on-line and point to a broken social contract. Well, I have some difficulty in seeing who broke the social contract if costs come through at ten times the original estimate."

As these regulatory limits come to be recognized, the upshot will almost certainly be the end of the era of cross subsidies in favor of residential customers. Similar price breaks have stopped for low-volume airline routes and for local telephone traffic. "This is likely to happen to electric rates no matter how our system develops," says Varley. "Preferential residential rates may not only be a victim of market development, they may in fact have been a cause of the market development."

The debate for even broader pricing reform was picked up and championed by Charles Stalon, who views pricing as one of the principal defects in the present system. He argues that pricing should follow the stages of the business cycle, to be demand-sensitive, not demand-perverse. "Utilities have made a fundamental error in pricing in order to cover their revenue requirements in a given year. They tend to raise prices in a recession to protect earnings, thereby aggravating the economic problems of their customers and leading to inefficient capacity use. During booms, they tend to cut the price, inflating demand and increasing the need for more capacity. In competitive industries the opposite occurs: Industries reduce prices in a recession to moderate the depth of the downturn and raise prices in boom periods."

"Utilities have made a fundamental error in pricing in order to cover their revenue requirements in a given year. They tend to raise prices in a recession . . . and during booms they tend to cut the price. . . . In competitive industries the opposite occurs."

Stalon

He places part of the problem on the regulator's love of precedent, much of which he traces to nineteenth century pricing policies. Stalon also blames the utilities' tendency to "enshrine capital recovery policies." The result is a pricing policy he views as "disdainful of economic efficiency, socially and economically destructive, but one firmly embedded because it is perceived as 'just' by utilities and regulators."

Proper pricing in his view would put the industry in the role of serving higher economic objectives, of helping fit the utility industry properly into the national and global economy. In short, pricing policies would no longer move the industry counter to the business cycle of the nation.

Specifically, he endorses "squeezing earnings in times of recession, and banking them in boom times. You don't have to earn a just and reasonable return in each and every period. This is just a custom of the industry; courts will allow cyclic recovery." To make this concept work, he favors removing ceilings on earnings in boom periods, using only variable pricing in long-term supply contracts, and moving the whole pricing mechanism out from under regulation. "I would argue that it is not possible to correct these fundamental pricing errors

Speakers

Jerry Geist, Chairman and President
Public Service Co. of New Mexico

Roger G. Noll
Department of Economics
Stanford University

Charles G. Stalon, Commissioner
Federal Energy Regulatory Commission

Theodore Stern, Executive Vice President
Energy and Utility Systems Groups
Westinghouse Electric Corp.

Andrew Varley,* Chairman
Iowa State Utilities Board

Eric Zausner, Senior Vice President
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Edward F. Burke,* Chairman
Rhode Island Public Utilities Commission

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John W. Ellis, President and Chief Executive Officer
Puget Sound Power & Light Co.

Alex Fremling, Vice President
Administrative Operations, EPRI

Michehl Gent, President
North American Electric Reliability Council

Dominic Geraghty, Assistant to the President
EPRI

John H. Gibbons,* Director
Office of Technology Assessment

Frank Griffith, Director
Iowa Public Service Co.

George M. Hidy, Vice President
Environment, EPRI

Narain E. Hingorani, Vice President
Electrical Systems, EPRI

Gordon C. Hurlbert,* President
GCH Management Services, Inc.

Milton Klein, Vice President
Industry Relations and Information Services
EPRI

Robert K. Koger,* Commissioner
North Carolina Utilities Commission

William J. Lindblad, President
Portland General Electric Co.

Henry R. Linden,* Executive Advisor
Gas Research Institute

William McCollam, President
Edison Electric Institute

Katherine A. Miller, Senior Planning Economist
EPRI

Laurence I. Moss,* Consultant
Energy Design and Analysis

C. Burton Nelson, Director
Regulatory Relations, EPRI

J. Dexter Peach, Assistant Comptroller General
Resources, Community, and Economic Development Programs
General Accounting Office

Sam Schurr, Deputy Director
Energy Study Center, EPRI

Chauncey Starr, President Emeritus
EPRI

John J. Taylor, Vice President
Nuclear Power, EPRI

Grant P. Thompson,* Executive Director
League of Women Voters

Victoria J. Tschinkel,* Senior Consultant
Landers, Parsons, & Uhlfelder

Stewart L. Udall,* Attorney at Law

Judith B. Warrick, Principal
Morgan Stanley & Co., Inc.

David C. White, Director
Massachusetts Institute of Technology

Dean G. Wilson,* Executive Vice President
Lone Star Steel Co.

Herbert T. Woodson, Associate Dean
Development and Planning
University of Texas

Kurt Yeager, Vice President
Coal Combustion Systems, EPRI

Frank Young, Associate Director
Electrical Systems, EPRI

Richard W. Zeren, Director
Planning and Evaluation, EPRI

*Advisory Council

through the present system. The only way we are going to do it is through the marketplace."

Most of the pricing reforms discussed—from the elimination of cross subsidies to demand-sensitive prices—would serve the industrial customers well. But what about the captives, the residential customers? The clear implication is that their rates will have to rise and that they in turn will act to cut their own costs. Some will undoubtedly seek relief through political channels; others will actively seek to reduce demand through conservation; still others will organize into tough-minded shopping cooperatives. This remains one of the key unresolved problems of the future for which there is no consensus. Roger Noll believes we "will have to find a way to subsidize low-income residential customers but without creating irrational pricing for industrial customers." Time-of-day-based rates will very likely be part of the answer. "I believe a rational residential pricing system can be worked out over time," says Varley, "with prices more nearly approaching the cost of production. But we need to remember that hour-by-hour fluctuation in price would be politically intolerable. I can't imagine customers waking in the morning to hear the spot energy prices on the radio."

The economic deregulation of electricity generation, as this suggests, would usher in a new set of political problems to replace those it left behind. There is already enough rumbling about the problems of inadequate regulation—ranging from the stock market crash to the deteriorating state of airline service—to suggest that a backlash could be brewing against the decade-long trend of economic deregulation.

Is deregulation inevitable? Only time will tell. One thing *is* certain, the underlying economic forces are at work in this industry as in others, and utilities will have to respond. Regulated or unregulated, the utility industry will see changes in the coming years. ■


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RETURN POSTAGE GUARANTEED

Employee Loans With Technology Payback

More utilities are discovering the benefits of sending technical staff members for a tour of duty at EPRI. New flexibility in the loan program promotes the quality of the experience and the value of the technology transfer.

Employee loans between EPRI and its member utilities are taking on a new look. As always, they hinge on the value of borrowing and sharing experience, of learning a complementary frame of reference. But utility employees, the more typical "loanees," as they're usually known, are less often becoming EPRI research managers today and more often becoming agents of technology transfer.

"Tell us what you want your people to learn, and we'll work to expose them to *that*," says Bill Minor, who heads EPRI's staff planning and recruitment. The new emphasis is on imparting Institute products, knowledge, and skills that can be directly applied in a utility setting. EPRI is therefore welcoming technical staffers from a widening range of utility backgrounds, men and women who come to vacuum up the state of the R&D art for use back home.

A shift in outlook

The showcase of this new look is EPRI's Fluidized Combustion Program and three FBC demonstration projects at member utility plants in Colorado, Minnesota, and Kentucky. Program Manager Shelton Ehrlich has pioneered employee loans as a means of technology transfer. During the past three years, no fewer than nine professionals from seven utilities have worked with Ehrlich's group, either at Palo Alto or in the field, learning by doing what Robin Moulder of Union Electric calls "graduate study, getting a master's degree in fluidized beds."

By no means do all the new-look loanees work with FBC. Four engineers, from as many utilities, have worked in EPRI's Energy Utilization Department, helping to shape a growing research effort in demand-side planning and end-use technologies. Two are there now, working on cool storage and electric alternatives to cogeneration.

EPRI's Nuclear Power Division has the greatest number of loanees—23 during 1988, many of them from abroad and working in the context of research information exchange agreements with EPRI.

More hands-on technology transfer to U.S. nuclear power plants is in the offing, too. Expanding on this successful ongoing program of long-term employee loans, EPRI's nuclear power research managers and their industry advisers are evaluating the idea of adding very short-term loans—only two or three months—for nuclear plant O&M personnel. Such fast orientations would be virtual shopping sprees at EPRI, targeting R&D results that utilities can use to cut plant operating costs.

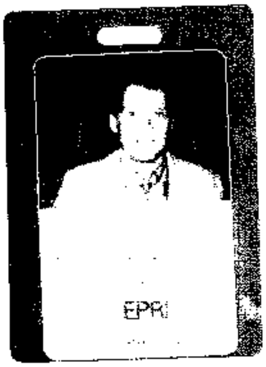
What's new in all this is the form, not the fact. EPRI opened its doors 15 years ago with a tradition of on-loan employees already in place for managing utility industry research. Indeed, the Institute assumed responsibility for a number of EEI and other industry-sponsored projects that had been managed by utility people. Also, because a working research plan had to be implemented quickly, EPRI filled several staff positions with utility engineers and researchers.

Today, with a staff of more than 700 individuals, EPRI is far beyond a once-foreseen ultimate staff of perhaps 200, and staffing expectations have changed. For example, an early notion that as many as a third of EPRI's professionals at any time would be on loan from industry ranks did not prove out. Even so, a total of more than 100 individuals have come and gone from EPRI under some form of loan agreement during the past 15 years.

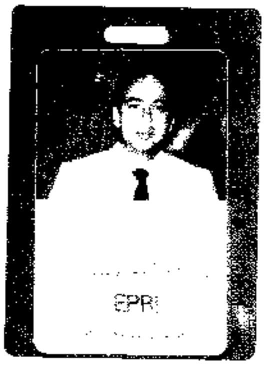
For most of that time, Minor says, "employee loans were a basic staffing tool for the Institute. The program focus was on what *we* needed." Of course, a loanee's work at EPRI built long-term benefit back home, but when EPRI began to accumulate near-term research results, a focus on more-systematic feedback was needed. Also, some loanees were joining the EPRI staff, thereby breaking the technology transfer loop.

For Minor, realization of what could be done with a 180-degree shift in outlook came in the aftermath of Three Mile Island, when he worked with EPRI's quick-response team, the Nuclear Safety Analysis Center. NSAC was heavily staffed with utility professionals (as well as representatives of nuclear systems firms), and its immediate fact-finding aim was to tell utilities what they needed to know.

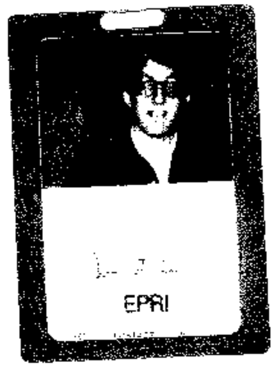
"What we've done now," says Minor, "is to look at employee loans as a way to improve technology transfer, not to fill regular EPRI jobs." The practice, when-



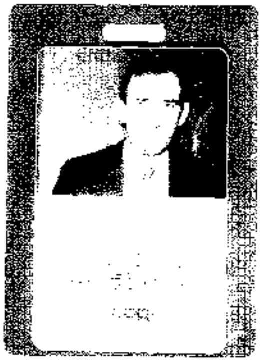
Paul Beatty
Duke Power



Rich Burke
Vermont Yankee



Joel Cehn
Pacific Gas & Electric



Jack DeVine
GPU Nuclear

Paul Ewald
Consolidated Edison

ever Minor can make it happen, is a critical look at staffing requirements—sitting down with EPRI program managers specifically to identify R&D tasks that can teach something of practical, transferrable value to a utility engineer or manager. "Then," Minor goes on, "we work with members to find people who can help us develop the programs involved, familiarize themselves with the content, and take it back home. Of course, we always try to keep things loose enough so that loanees are exposed to the Institute as a whole and take that exposure back, too."

Technology test and transfer

Unique opportunities for utility employee assignments in EPRI's Fluidized Combustion Program came along just at the right time, beginning in 1985. Here were R&D results nearly ready for turnover to the industry—new technology to be designed and built, started up, and run through extended on-line demonstration programs. Participation had evident value for any utility considering alternatives for its next capacity addition. Further, many tasks would be of the hands-on, real-world variety, foreseeably a quick, familiar fit for utility engineers. And finally, some loan assignments could be bite-size—six months or so at EPRI, plus comparable intervals at one or more plant sites.

Piloting the new use of loaned employees fell to Shelton Ehrlich, FBC program manager. But neither Ehrlich nor Bill Minor saw all the possibilities at once. As Ehrlich puts it, "To begin with, we needed someone to do an architect-engineer sort of job, someone who wouldn't be a long-term staff member." Ehrlich began a conventional search three years ago, seeking recommendations for a potential contract employee. To his surprise, an acquaintance at Baltimore Gas & Electric responded, in effect, "How about us? I think we can help you."

The upshot was Chet Lawrence, whose long suit is construction project management, which includes the balance-of-plant expertise EPRI needed. He became the project manager responsible for planning EPRI's role in the three FBC demonstrations: a new 160-MW unit, the world's largest, at a TVA site in Kentucky; a 130-MW unit being substituted for a pulverized-coal boiler by Northern States Power in Minnesota; and a 110-MW circulating-bed FBC unit at a Colorado-Ute Electric plant in Colorado.

Even though Lawrence clearly had major responsibility for an EPRI field research program, his two-year assignment, except for a living-cost differential and his EPRI business expense, was paid by Baltimore Gas & Electric. This new departure in employee loan transactions underscored the utility's purpose: to learn about fluidized-bed combustion and establish a decision process before the time comes to select and design its next capacity addition.

When it came to field loan assignments, Ehrlich and his colleagues, with a dozen years of development behind them, were pretty sure which utilities were most interested in the technology. Nevertheless, the watchword was to put member utilities in the driver's seat. Solicitation letters therefore went to a somewhat larger group. Utilities would volunteer for the program, nominate candidate employees, and describe the desired emphasis of work experience.

Recalling that letter, Minor says, "When a utility nominated someone, Ehrlich interviewed, and then we set up a specific development program for that person. And that was key. It was so simple, but it made all the difference—arranging with utilities what they wanted to learn."

The basic plan called for a loanee to work six months at EPRI, followed by six months at each of three FBC demonstration plants. But some utilities have sought greater emphasis (more time) on one demonstration; others have cut the loan term from two years to as little as four months.

Proof of the approach is its acceptance by seven member utilities: Baltimore Gas & Electric, Commonwealth Edison, Consolidated Edison, Duke Power, Salt River Project, Union Electric, and Wisconsin Electric Power. Myron Horton of Duke was one of the first to join the program, Paul Beatty is in it now, and Ehrlich glows when he says, "We've now heard from Duke—their next coal-fueled plant will be a fluidized bed."

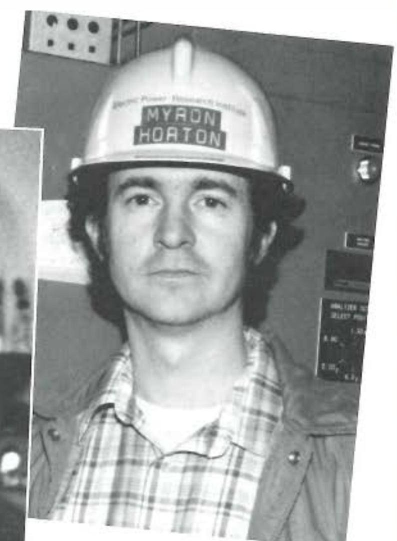
Hands-On Technology Transfer

Three utility power plants using atmospheric fluidized-bed combustion of coal for power generation (and one small pilot plant that laid much of the R&D groundwork) occupied a stream of utility employees on loan to EPRI during the past three years. These demonstration plants, hosted by TVA, Northern States Power, and Colorado-Ute Electric, are the last step in making FBC a commercial option for the next round of baseload generation capacity.

Chet Lawrence of Baltimore Gas & Electric spent two years at EPRI planning the Institute's role in the demonstration programs. Most of the other loanees spent from four to six months at EPRI before working as test engineers or site representatives in the field. These men and women range from an Engineer II on a corporate rotation plant to a superintendent of operations at a baseload coal-fired plant, from 25 to 41 in age, and from 1½ to nearly 20 years in utility experience. In addition to Lawrence, the individuals and their EPRI terms are Paul Ewald and George Germano of Consolidated Edison (10 and 6 months, respectively), Myron Horton and Paul Beatty of Duke Power (25 and 18 months), Dirk Andreas of Commonwealth Edison (4 months), Monica Burch of Salt River Project (6 months), Jeff Knitter of Wisconsin Electric Power (24 months), and Robin Moulder of Union Electric (22 months). □

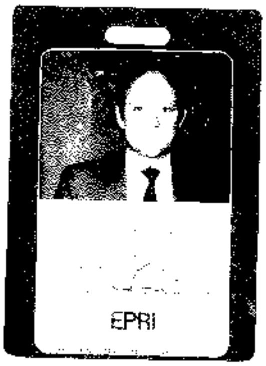
Monica Burch

Chet Lawrence



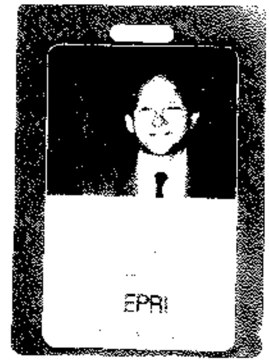
Myron Horton

John Fishbaugher
North American Energy Services

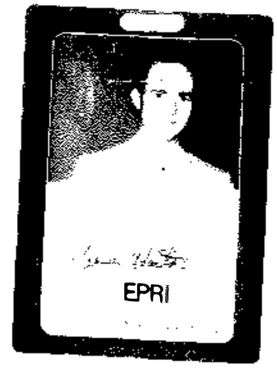


Jim Fortune
Virginia Power

Don Geistert
Southern California Edison



Jerry Harper
TVA



Myron Horton
Duke Power

Reflecting on the experience

Reactions of loanees—those who have returned home as well as those who are still with EPRI—say a lot about the program, utility motivations for taking part, and the loanees themselves. Some loanees extend their experience in a technology while at EPRI; others contribute a special expertise and take away something new from the R&D context.

Chet Lawrence claims, "When I came, I didn't even know how to spell AFBC." But because what he learned at EPRI had such specific value for Baltimore Gas & Electric, he wrote periodic reports, visited his home office two or three times, and on one occasion briefed the utility's chairman and executive management group. "My reports weren't tutorial about what Baltimore should do. I tried to provide insight about what and where FBC problems were and how EPRI was working toward solutions."

Questioned about the efficiency of a loanee, the time lost in shifting to an R&D viewpoint, Lawrence has a quick reply. "You're no more handicapped than a new person anywhere. As for the utility's benefit," he adds, "it isn't any different from sending someone to school and then finding out afterward that he can directly use only part of what he learned!

"I'd like to think of three winners from this kind of program: the utility, EPRI, and me, too. Baltimore wins by becoming more familiar with a technology and with what else is going on at EPRI. Reports and benefits assessments are fine, but firsthand experience, knowing people and spending time with them, is better."

A potential problem for any utility employee on loan at EPRI is that he or she is seen as a surrogate for all utilities—"What is the utility viewpoint about such-and-such?" On the few occasions that Lawrence felt this reaction, his good-natured disclaimer was, "Wait a minute! You've worked with more utilities than I have; you probably know better than I."

An emphasis on short terms, rotation among field assignments, and specific technology transfer are new features in EPRI's handling of utility employee loans; but they aren't requirements. The idea is for the program to be attractive, and flexibility is important. Participants don't have to do things just one way.

Jim Fortune, for example, is on a three-year loan from Virginia Power, serving as a project manager in EPRI's Advanced Power Systems Division. He works in the Engineering and Economic Evaluations Program there because economic feasibility will be the point on which Virginia Power decides when to expand a new combined-cycle power plant into one with integrated coal gasification on the front end.

At one time manager of mechanical engineering at Virginia Power, where he has worked for eight years, Fortune more recently was the point man for the advanced gas turbine at the new combined-cycle plant. Now he hopes for similar responsibility when the gasification stage is integrated. Appropriately, Fortune's EPRI work involves projects with two other utilities (Baltimore Gas & Electric and Florida Power & Light) that are researching the IGCC power option.

Fortune got to know most of his EPRI colleagues during earlier cooperation with them on a federal synthetic fuel development grant proposal that fell through. In fact, he later requested the employee loan as a means to stay current on IGCC. Still, the EPRI atmosphere is different for him. How?

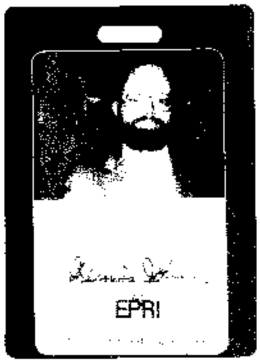
"The product. I'm from engineering and construction. We build things. Our product is hardware, a power plant. EPRI's product is information. This means a lot more involvement in details." Fortune breaks into a smile as he thinks of his own experience. "You learn by doing when you're on loan. I'm crunching numbers here, and I hadn't done that for years!"

Applying utility perspectives

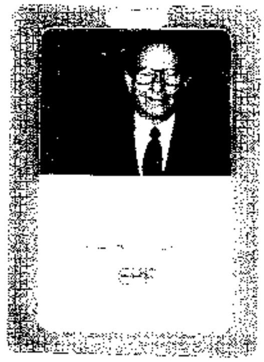
Don Geistert, 18 years with Southern California Edison, is with EPRI's Energy Utilization Department for a year, specializing in cool storage technology. This was also his most recent responsibility in the utility's marketing area (in customer service), so to some extent Geistert is transferring technology into EPRI. At least, communicating the utility's needs and viewpoints is one reason for his assignment.

Another reason, perhaps equally im-

rry Jackson
abama Power



Dennis Johnson
BPA



Charles Knauf
Long Island Lighting

Jeff Knitter
Wisconsin Electric Power

Chet Lawrence
Baltimore Gas & Electric

portant, is to gain a more intimate and detailed knowledge of EPRI. "I have an understanding to spend most of my time on cool storage," he says, "but also to dabble in all the end-use technologies, especially the industrial ones."

Because "out of sight, out of mind" is a potential problem for a loanee, Geistert returns to his Southern California Edison office for at least one day every six weeks. It isn't a structured show-and-tell occasion, but he makes a personal point of contacting individuals for whom he has potentially useful information. And he finds himself taking questions for further exploration when he returns to EPRI. "Sometimes, I find the answer," he says, "but sometimes I just find out what is the best channel and pass that along."

Steve Pertusiello of Consolidated Edison in New York, like Geistert, works in marketing, specifically in conservation services. His loan assignment at EPRI lasted 18 months, ending three years ago, in March 1985. Also like Geistert, he worked in EPRI's Energy Utilization Department, first (because of his Con Edison experience) in the establishment of EPRI's lighting research activity. Later he worked in electric transportation.

Pertusiello continues his EPRI connection now as a member of the advisory task force on residential and commercial energy use. He also serves informally as an EPRI resource among his professional colleagues at Con Edison and elsewhere in the industry. "People ask me about EPRI and its inner workings," he says, "even if only to define things like RPAs and RPCs or to distinguish between an authorized budget and a committed budget. The company," he adds, "values the broader contacts I gained for our end-use planning and management."

Speaking easily and warmly of the loan as a family experience, Pertusiello recalls, "We rented out our house in New Jersey and rented another near EPRI. We liked the winter in Palo Alto—certainly the absence of shoveling." However, California produced a couple of earthquakes while he was on loan, "and we did not like that," he says emphatically.

Pertusiello isn't alone. Earthquakes are one of the eventualities that many loanees today discuss with Nancy Martin, a relocation consultant retained by EPRI. "We try to help clients see earthquakes here the same way midwesterners see tornadoes and hurricanes. They're all so dramatized in the news elsewhere. We also talk about more mundane things like houses that don't have attics and basements, and fenced lots that are so much smaller than newcomers are accustomed to.

"We get all kinds of questions and follow-up calls," says Martin. "About car licensing. About schools—we furnish lists of Montessori, Catholic, and alternative schools, of community colleges and universities. We know places that offer scuba diving lessons, and where to go to cut a Christmas tree. We can advise a teacher who wants to renew a credential here."

Broadening options

Relocation consulting smooths the way for loanees. Methodical changes in EPRI's budgetary and administrative practices have smoothed the way for EPRI and utility managements. The changes have added flexibility to the loan program. Like diversity in natural species, flexibility is proving useful for meeting different utility needs, not to mention for shaping useful opportunities among EPRI's quite different R&D groups.

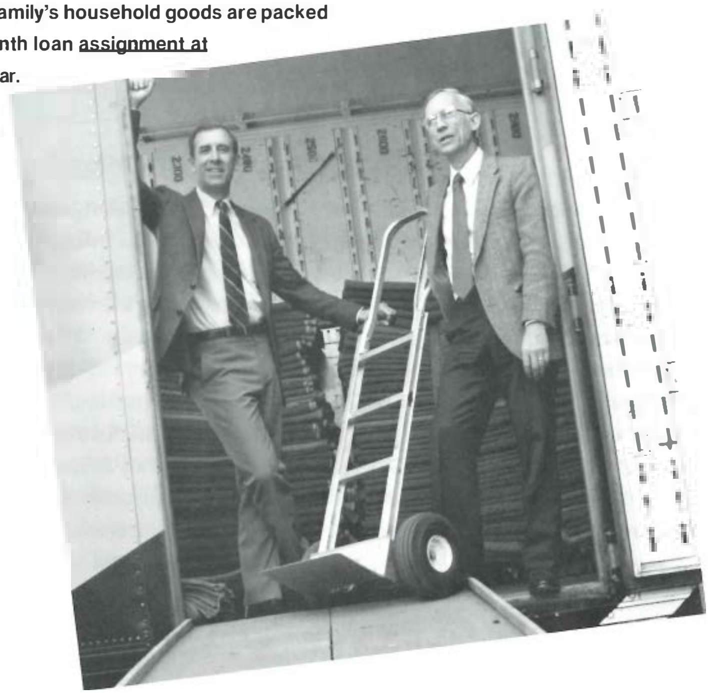
An early problem Minor wrestled with was that of employee loan costs. Both direct and indirect, they were a major concern—an obstacle or an incentive, depending on your viewpoint.

Historically, EPRI had paid everything, even reimbursing utilities for loanee salaries and benefits. This was a financial incentive to utilities. The Institute gained the obvious, immediate benefit of productivity from employees familiar with utility values and protocol. Utility benefit was less tangible and longer term, involving the loanees' professional development, understanding of EPRI, and cultivation of relationships with its people.

When budgets became more constrained in the 1980s, the use of on-loan employees became less attractive. But at the same time, pressures were increasing to improve technology transfer. Out of these conflicting requirements came a broadened scope for the loan-in program and a change from historical funding priorities.

In most cases, utilities pay the salary

Loans Go Both Ways



Jack DeVine of GPU Nuclear (left), now managing an EPRI research program of LWR development, talks with EPRI's Bob Shaw as the Shaw family's household goods are packed for a 15-month loan assignment at GPU Nuclear.

Employee loans tend to build webs of relationships that reach out over space and time, quite apart from the technologies involved. For example, Jack DeVine of GPU Nuclear, now in his third year at EPRI, is senior manager of the Advanced Light Water Reactor Program. Coincidentally, Bob Shaw of EPRI's Nuclear Power Division has just gone to Parsippany, New Jersey, where he'll spend the next 14 or 15 months getting GPU's new program of nuclear power investment risk assessment up to speed.

DeVine believes utility employees bring special expertise and authority to new LWR research that can't be matched any other way. His role at EPRI thus continues a tradition begun with his predecessor, Dan Noble of Consumers Power, who managed the same program in 1985 and 1986.

Shaw's opportunity to start up a GPU program developed in part from his R&D counseling with the utility on cleanup problems at its damaged Three Mile Island reactor. But the specific invitation came from Bob Long, a GPU Nuclear vice president and EPRI adviser who knew something of Shaw's capability. How? Ten years ago, then an engineering department chairman at the University of New Mexico, Long himself came to EPRI on loan, and he worked with Bob Shaw. □

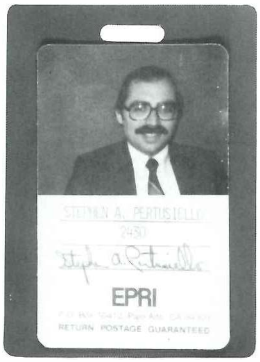
Robin Moulder
Union Electric

and benefit costs of their employees on loan, and EPRI picks up the rest, primarily the relocation expense and an individually worked-out cost-of-living differential. Such an arrangement reinforces the premise that a loanee has a specific mission on his or her utility's behalf. Elaboration on this point comes from Karl Stahlkopf, who directs materials and systems development in EPRI's Nuclear Power Division. "Utilities see the loans as investments in their future. They get an in-depth perspective on EPRI and the practical results of its research. This is why they are willing to send us some of their best people."

The Institute is also building more flexibility into the length of the loan term, which in the past has typically been about two years. The terms are now more often set according to the purpose and scope of the work, from heavy project management to short tutorials on specific applications. Stahlkopf emphasizes the value of longer terms: "For a loanee managing a complicated project—for example in advanced LWR design—it may take him six months to assimilate EPRI's approach to the research and another six months to become sufficiently grounded in the details; that's a year before we have a fully integrated, working staff member.

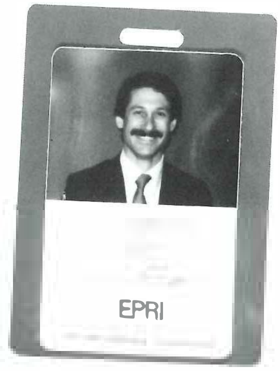
In some cases the nominal length of term is deceiving. Minor points out that the basic program for the FBC demonstration loanees is two years. "But those people aren't just here. They're at other

n Noble
nsumers Power

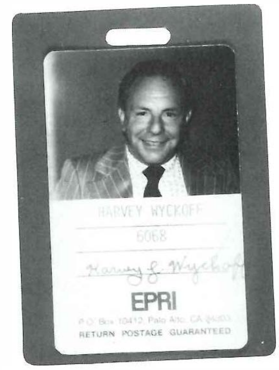


Steve Pertusiello
Consolidated Edison

Gary Powell
Salt River Project



Paul Stapleton
San Diego Gas & Electric



Harvey Wyckoff
Commonwealth Edison

plants getting hands-on experience . . . they're not doing EPRI project manager work. The utilities know their people will come back as more-valuable employees in very practical and specific ways."

Shorter-term loans are appropriate for many loan projects, and the Institute is particularly interested in the technology transfer advantages of a quicker experience. Minor values short loan terms in part because more individuals can be accommodated. "When the Energy Management and Utilization Division sent out letters, more utilities responded than we had staff to manage or work to be done. But it's hard to say no to a member utility that wants to participate. How do you say no to a student or to your customer! I don't think we can afford to do that."

Indeed, the rationale for utility employee loans to the EMU Division is somewhat different. "Their utility experience helps keep us in focus," says Minor. "They calibrate our programs, letting us know what electricity users, their customers, are thinking." Some of these loans are only six months long, leading Minor to observe candidly, "They may not produce at the same level as a longer-term person, but they don't cost that much money, perhaps only a tenth the cost of a contractor, and they bring a variety of market experience."

Benefits all around

Shelly Ehrlich can think of a million reasons why employee loans make sense, and some of those reasons aren't specific to his program. For example, "There are very few fossil fuel plants of any kind starting up today, and startup is different from routine operation. But FBC units have a lot of systems in common with other coal-fired plants, so they're good training assignments."

Ehrlich warms to the subject when he recalls his own early work with FBC some 20 years ago. "There is unparalleled value in doing experiments. You get technology transfer into your own head. It's an opportunity to learn the *meaning* of data. Data points are always scattered, and judgment is needed. It takes experience to understand, interpret, and apply test results.

"Another thing—a test engineer gets instant feedback! Very rewarding. If you're an engineer in design or operations, it may take months or years before you know the results of what you did." Ehrlich adds a thoughtful note, "People who work in the loan program conquer things. They feel good about themselves and about EPRI."

Strong, positive feelings about the loan experience can produce ripple effects beyond any immediate technology transfer from EPRI to a member utility. Loanees become more effective networkers, in their utilities and industrywide. Some, like Pertusiello, have continuing advisory connections with EPRI. Others serve as informal R&D information channels between their colleagues and EPRI. All of them acquaint a wider spectrum of utility midmanagement and working-level staff members with how R&D results from EPRI can help them.

After nearly three years, Ehrlich insists that the new loan program works even better than he expected. "The most noticeable thing about it is the passion, the enthusiasm, people have brought to it. The surprise is how that rubs off on everyone else. *That* is why it's so good for us." ■

Of the nearly 30 engineers (from 21 member utilities) on loan to EPRI during the last three years, these eight worked entirely at outlying EPRI facilities or were just arriving as this article was prepared.

Dirk Andreas
Commonwealth Edison

Monica Burch
Salt River Project

Billy Feller
Texas Utilities Electric

Jerry Fourroux
TVA

George Germano
Consolidated Edison

Bob Hayman
Consolidated Edison

Roy Lindley
North American Energy Services

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This article was written by Ralph Whitaker, feature editor. Background information was provided by Shelton Ehrlich, Coal Combustion Systems Division, and Bill Minor, Human Resources Division.

Concrete Containments Handle the Pressure

Computer simulations of how nuclear containment buildings respond to overpressurization have been validated by tests on large-scale models, with results adding encouraging evidence for nuclear plant integrity.

Since the Three Mile Island accident in 1979, utilities and regulators have given increased attention to the containment buildings that surround nuclear reactors and their ability to withstand the pressures that could be produced in severe accidents. It was containment, standing behind other safety-related systems as a final and formidable barrier, that kept the radioactive release from the TMI accident from being harmful. Questions remain, however, about the structural response of containments to accidents even more severe—although much less probable—than TMI's. According to some of these accident scenarios, containments could be pressurized at levels far beyond their design basis.

As part of the effort to model severe accidents, researchers aim to predict the pressures at which containments would fail and the probable modes of failure. This information will be used to predict the level of radioactive releases from accidents and to reassess the overall risks of reactor operation. The challenge involves experimental and analytic work, using data from laboratory and large-scale tests to develop more-accurate software for modeling containment response to pressures above design basis.

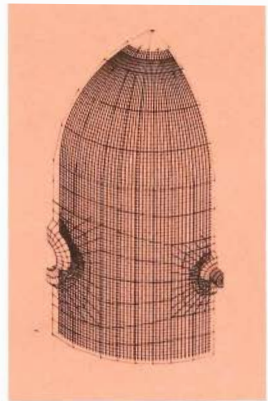
Although this R&D focus on highly unlikely accidents might seem pessimistic, the results pertaining to the steel-lined concrete containments found on about 75% of U.S. commercial reactors are actually quite encouraging. The evidence accruing from laboratory and analytic work conducted for EPRI and NRC since the early 1980s indicates that concrete containments will leak—but not catastrophically break—when overpressurized in severe accidents. These findings, which revise the model of containment response used in the federally sponsored *Reactor Safety Study* (WASH-1400) and other influential risk assessments, suggest that the release of radioactive effluent from a breached, concrete containment would happen over a longer period of time, be ultimately smaller, and pose less risk to public safety than previously assumed.

The development of this new model of concrete containment response, although still not complete, reached an important milestone in July 1987 in an NRC-sponsored program at Sandia National Laboratories near Albuquerque, New Mexico. Scientists there used nitrogen gas to pressurize a large-scale model of a steel-lined concrete containment building to failure and observed the leak-

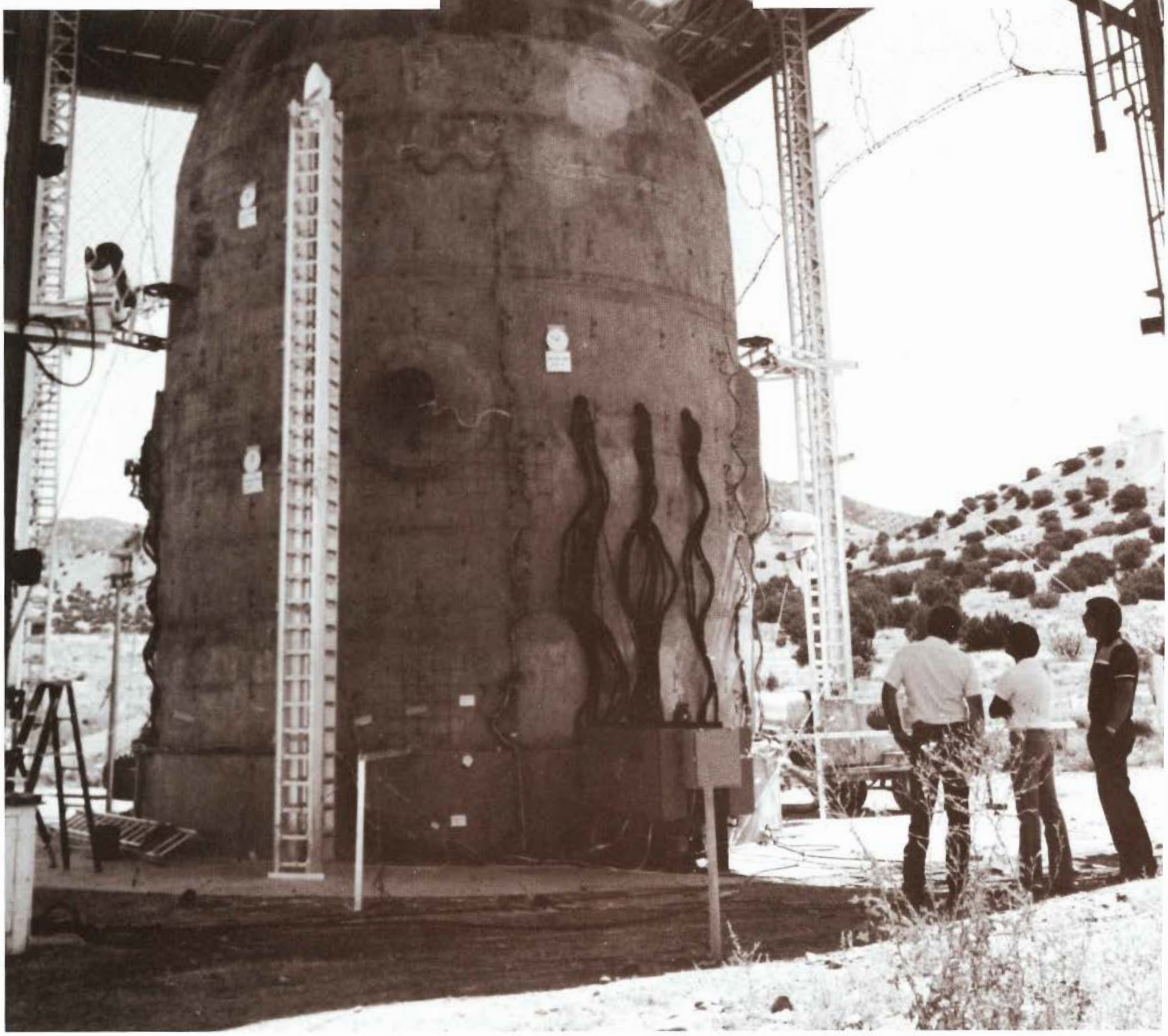
Modeling With Concrete and Computers

To provide data for improved computer tools, scientists under contract to NRC at Sandia National Laboratories constructed a 1/6-scale model of a reinforced concrete containment dome and pressurized it to failure. Using its ABAQUS code, EPRI modeled the structure prior to the test and proved most successful among 10 participating organizations in predicting the leak-before-break failure mode and the pressure and locations at which the structure failed.

Computer-generated model



Large-scale concrete containment model



age phenomenon firsthand. "Although no sweeping conclusions can be drawn from the test, I think it is going to profoundly affect our thinking," said Thomas Murley, director of NRC's Office of Nuclear Reactor Regulation. "After the Chernobyl accident, what happened in the public's mind is that containment failure became equivalent to no containment. The test puts in perspective what containment can do, even when it fails."

At EPRI, the test provided the added comfort of verifying the accuracy of the computer codes and methodologies developed over the past decade to predict the behavior of concrete containments and other structures used in the utility industry. Of the 10 prestigious research organizations from North America and Europe invited prior to the test to predict the results, EPRI was alone in predicting the mode of failure and most accurate in identifying the pressure and the locations at which the structure would fail.

This demonstrated ability to predict complex structural behavior is just one product of EPRI-sponsored containment integrity research that has potential benefit to nuclear utilities. If the leak-before-break hypothesis is borne out by continued research, it is likely to be incorporated in containment performance criteria now being developed by NRC and possibly in calculations of radioactive releases (source term) from postulated accidents. As suggested by comments from Murley and other senior officials in NRC, leak-before-break could strengthen confidence within the regulatory agency as to the adequacy of existing concrete containments. At the same time, containment integrity research has produced test-verified tools that utilities can use to evaluate their containments, draft emergency plans, and if necessary, cope with accidents that might arise.

Containments Under Stress

The evolution of EPRI's leak-before-break model began in the early 1980s when Anatech scientists under contract to EPRI began to look closely at the different components and materials that compose a concrete containment building. All the concrete containments used in the industry are kept leak-tight by a steel liner plate from ¼ to ⅜ inch thick, which is anchored to the inner surface of a reinforced or prestressed concrete wall. Inside the concrete wall is a supporting grid of steel reinforcing bars (rebars). In addition, the entire structure contains several specially designed penetrations for cabling, piping, personnel, and equipment entry.

To Y. R. Rashid, president of Anatech and the individual often credited with the development of the leak-before-break model, it became apparent that the model of containment response used in WASH-1400 and elsewhere did not realistically reflect the complexity of concrete containments and their probable behavior under stress. "The prevailing model was based on simple design concepts and the idea that the steel liner would act like a membrane and stay leak-tight until both liner and concrete would rupture, something like a bladder or balloon," he explains.

"From our experience in the modeling of concrete and similarly complex structures, we postulated that the accepted model did not adequately account for the interaction of the liner and concrete that was likely to occur at high internal pressures, nor for the interaction of the concrete and the rebar, nor—for that matter—for the behavior under stress of the concrete itself. Moreover, we judged that all these factors would be further complicated by the penetrations and other forms of discontinuity in the containment structure."

After preliminary analyses using advanced, nonlinear modeling techniques, Rashid proposed a new scenario in which local stresses would cause tearing and leakage through the steel liner before any disruptive break in the concrete. According to the revised model, the venting of the containment's internal pressure through leaks in the steel liner would prevent any such large break from happening at any point in a severe accident.

Putting Concrete to the Test

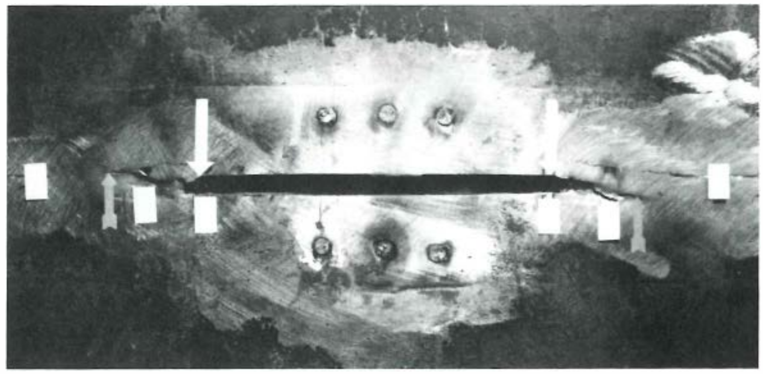
To test and develop this hypothesis, EPRI began a coordinated effort with NRC in 1983 in which experimental and analytic work proceeded in parallel. The first phase of laboratory testing, carried out in a preexisting NRC test rig, subjected concrete slabs and sections of steel liner to powerful loads produced by hydraulic rams.

These experiments were followed in 1984 by similar tests on concrete slabs with liner plates attached, and then in 1985 and 1986, on steel-lined slabs of concrete that included penetrations identical to those in actual containments. For this latter phase of experiments, EPRI commissioned the construction of a unique multiaxial test facility at the Construction Technology Laboratory of the Portland Cement Association in Skokie, Illinois. The largest facility of its kind in the world, this torture chamber for concrete can support full-scale containment sections, subject them to loads totaling up to 50 million pounds, and monitor air leakage that occurs through the cracks in the steel liners and concrete.

As results arrived from the new facility in 1986 and early 1987, EPRI research managers increasingly gained confidence in both the leak-before-break model and the ability of the newly adapted ABAQUS code to predict the response of concrete containments to pressures above design-basis levels. By progressing from the earlier tests on simple structural elements to investigation of prototypic containment wall sections, researchers had been able to gather data and gradually refine their models of the structural response of concrete. In addition, they were able to adapt the EPRI-developed ABAQUS code, a generic tool previously used for structural anal-

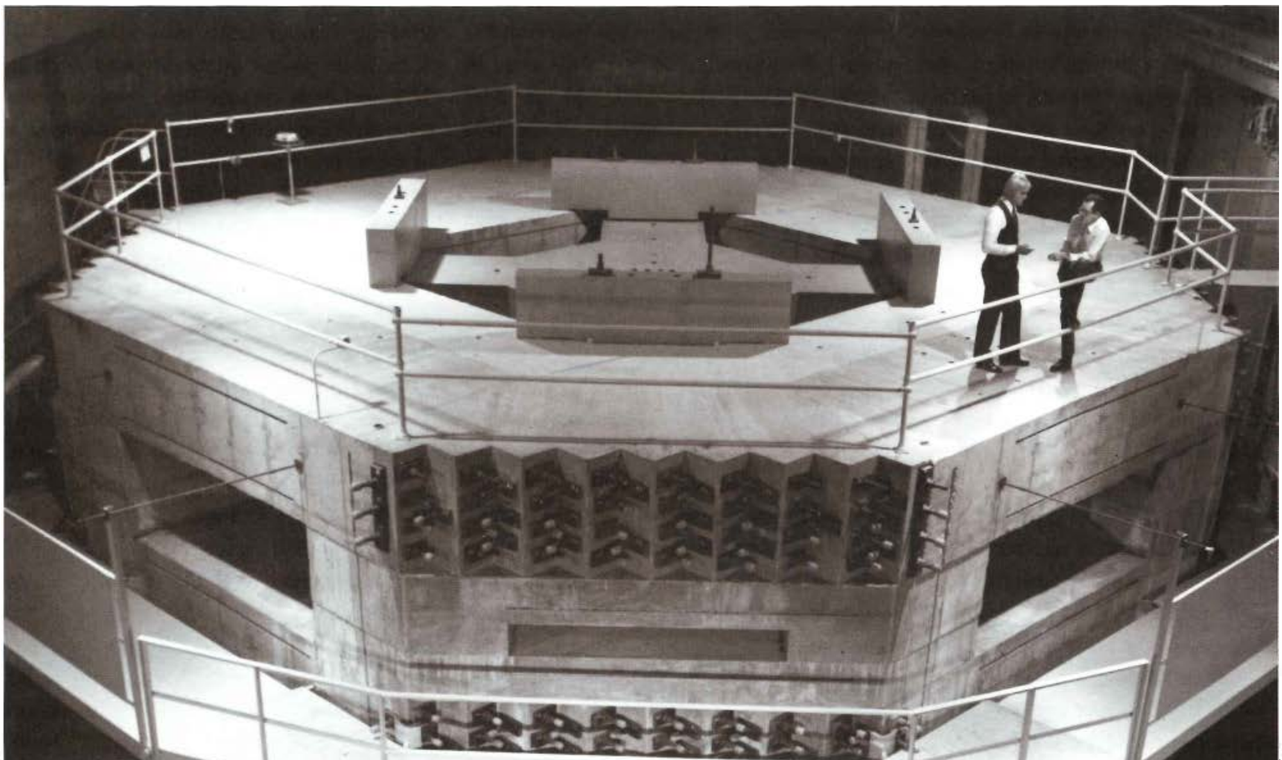
Testing Structural Response

To model the structural response of concrete containments to pressures above design basis, EPRI sponsored construction of a unique multiaxial test facility at the Portland Cement Association in Skokie, Illinois, that uses hydraulic rams to subject prototypic steel-lined concrete containment sections to the stresses they could encounter in a severe accident. Results showed cracking rather than disruptive failure in the concrete, with a tear in the steel liner plate, causing the sections to leak but not break at pressures well above design basis.

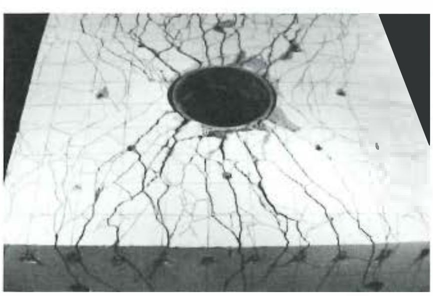


Tear in steel liner

Multiaxial Test Facility



Cracked slab



yses on systems ranging from power plant piping to nuclear waste shipping casks, for an important, new specific application.

The Trial in the Desert

A decisive test of the code and the leak-before-break hypothesis, however, was still waiting in the desert in New Mexico. For this landmark experiment, NRC contractors at Sandia constructed a ⅙-scale concrete containment structure, 37 feet high and 22 feet in diameter, complete with penetrations of the kind found in actual containments. To bring the structure to failure, nitrogen gas was pumped inside through a hose. Outside, the containment walls were heavily instrumented to monitor leakage. The purpose of the test was to gather data to verify and develop such computer codes as ABAQUS.

At EPRI, research managers waited in anticipation of results that could help validate several years of hard work. "Of all the organizations invited to predict the test results, we and our contractors at Anatech were the only ones predicting depressurization from a tear in the steel liner," says H. T. Tang, subprogram manager for structural research in EPRI's Nuclear Power Division. "We were also predicting failure between 140 and 150 psig, as well as seven locations in the large-scale facility where failure was likely to occur."

As the facility was pressurized on July 28 and 29, onlookers were kept well back for protection against flying debris that might result from a disruptive failure; but as the test progressed, a loud hissing leak occurred instead. Several tears had developed in the steel liner, with a major crack near an equipment hatch causing the structure to depressurize at 145 psig, approximately three times its design pressure.

"Of course, we were pleased with the accuracy of our prediction," says Tang. "We correctly predicted the failure mode, were best among the organizations in predicting the pressure at failure, and identified the locations where the structure would fail. We're also glad to have some new data on the size of leaks and leak rates that we can use now to further develop our analytic tools."

As for the significance of the test to the postulated performance of full-scale concrete containments, Tang and other EPRI research managers emphasize that more work has to be done before leak-before-break can be established as a rule or a fact. For one thing, the Sandia test facility was designed with reinforced concrete, whereas more than half of the concrete containments in the industry are formed with a prestressed concrete that has not yet been put to a large-scale test. Although EPRI's tests at Skokie indicate that the leak-before-break model would apply to prestressed concrete as well, large-scale testing could help validate this aspect of the theory. Another factor in a postulated severe accident that was missing from the Sandia test was the heating of the containment walls; but analyses performed with ABAQUS indicate that the short-term heating allowed in most accident scenarios would not significantly alter the failure mode or pressure.

In addition, several features of the Sandia facility—the small steel studs that fasten rebar into the concrete, for example—could not be produced precisely to scale. At Anatech and at Sandia, scientists are taking these and other discrepancies in scale into account as they work to extrapolate the test results to full scale. In general, however, concrete containments used in the industry vary to such a degree that no single test could be expected to produce a definitive rule. Although full-scale tests can help to demonstrate structural response, plant-specific models will eventually be generated by analytic tools, such as ABAQUS, that can prove their accuracy and be steadily refined as test follows test.

Beyond the effort to predict containment response to severe accidents, research remains to be done on the nature of radioactive releases in a leak-before-break accident. In a scenario featuring a catastrophic rupture of the containment, a large inventory of radioactive debris could be assumed to be ejected into the environment all at once. In the case of a leak, however, time would allow radioactive debris to settle out of aerosols in the containment atmosphere and stay trapped on the walls and floor. Radioactive decay would also diminish the ultimate release, and a leaking containment would allow plant personnel time to take measures to mitigate the accident or warn or evacuate the public.

Although all these factors add up to the strong probability that a leak would not be as bad as a break, the task of determining the radioactive release from a leaking containment is a difficult one. Aerosols in the containment atmosphere would have to follow a tortuous route through torn steel and cracked concrete to reach the outside environment. And some aerosols could be expected to deposit particulates in small cracks, blocking leak paths. All these factors must be considered before EPRI can achieve the long-range goal of characterizing leak rates and releases as functions of time and pressure in various accident scenarios.

When this kind of modeling capability is complete, utilities and regulators will both benefit from an improved understanding of events that in all likelihood will never take place. "Utilities need this capability to understand the structural response of their containments in these postulated accidents," says Tang. "It's only by understanding what is possible that they can operate in the present with confidence and with a more realistic understanding of the risks." ■

This article was written by Jon Cohen, science writer. Technical background information was provided by H. T. Tang and Ian Wall, Nuclear Power Division.

TECH TRANSFER NEWS

End Users Tap Into Developmental Software

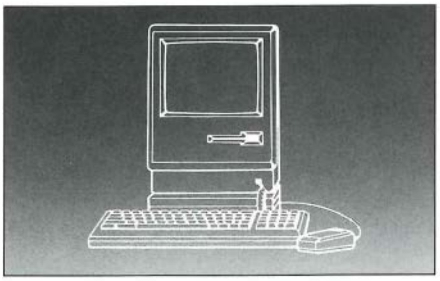
As personal computers and workstations become faster and more powerful, they are increasingly being applied to utility analysis, modeling, and data management tasks that once required mainframe computers and software. In addition to such obvious benefits to utilities as lower hardware costs and ease of use, the new microcomputer-based systems are enhancing the process of technology transfer.

R&D managers in EPRI's Advanced Power Systems (APS) Division have found that this flexibility, power, and portability also make microcomputer systems ideal for exhibiting and demonstrating developmental PC software at task force meetings and other industry events. The hands-on exhibits help EPRI identify user needs and at the same time familiarize potential users with new concepts and products.

APS launched this effort at the September meeting of the EEI Combustion Turbine Operations Task Force. In a hotel suite equipped with several PCs, dozens of task force members had the chance to work with several EPRI software programs now in development. This task force, a subgroup of the EEI Prime Movers Committee, involves plant personnel responsible for the operation of gas turbines used mostly for peaking operation. Although there is no formal relationship with EPRI, Robert Frischmuth, an APS project manager, acts as the liaison with this group: he keeps them informed on pertinent EPRI research, and the task force keeps him up to date on current problems in the field.

Both contractors and EPRI staff were on hand at the September meeting to guide task force members through program routines on the PCs, solicit their comments, and discuss possible enhancements and improvements. Lively discussions ensued as users experimented with the Electronic Bulletin Board, the data base program ERAS for tracking turbine system and component failures, the diagnostic program Efficiency—MAP, and the hardware/software tool Gas Turbine Expert System for diagnosing certain combustion turbine problems.

"Rather than just standing and looking, users became part of the software exhibits," says Clayton Smith, designer of the ERAS system. "Others clustered around the users, and soon we had frank discussions in progress, including some very constructive criticism." One direct result of the exhibit, Smith reports, is the



addition of new help screens to the ERAS program.

In the case of the Electronic Bulletin Board, the exhibit helped EPRI staff familiarize users with a whole new system for exchanging information and staying up to date on maintenance problems and solutions, R&D news, and other developments around the industry. The Electronic Bulletin Board was developed in-house at EPRI, where it is maintained and updated on a host PC. A utility employee can use a PC equipped with modem and data communications software to dial the Electronic Bulletin Board, scan its contents, and add items, if desired.

"Because the bulletin board concept is relatively new, hands-on demonstrations are especially valuable in helping utility users get acquainted with it," says Frischmuth. "In this case, as with other software products, the user input helps us develop a better product and also reduces the amount of promotion and explanation needed to transfer the product at a later stage in its development."

Following on the success of the September exhibit, APS repeated the activity at meetings of the division's own task force and advisory committees in January 1988. ■ *EPRI Contact: Robert Frischmuth (415) 855-2579*

Electronic Information on End-Use R&D

Two new personal computer software programs, MEDIABASE and EUCATALOG, are available to help utilities retrieve information on EPRI products and activities related to electricity end use.

The MEDIABASE software is a catalog of individual slides, slide sequences, photographs, charts, videotapes, and other materials from the Energy Management and Utilization (EMU) Division's extensive collection. With specialized peripheral equipment, the program displays color images, together with pertinent information; sorts and selects items on the basis of the user's criteria; and prints images selected by the user. In the future the system might be adapted for the expanded storage and improved imaging made possible by optical disk storage technology.

EUCATALOG lists all information contained in EMU's printed 1988 *End-Use Catalog,* plus additional reference data on each research project. The program sorts and selects R&D products for review on the basis of a wide variety of user-selected criteria. It also displays and prints lists of items the user has tagged for ordering.

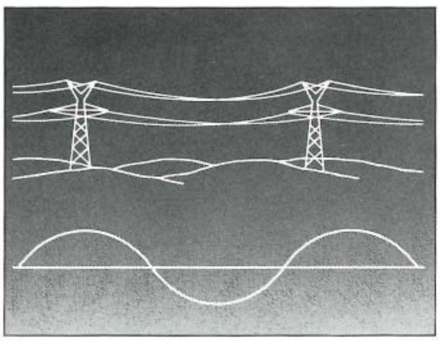
EPRI plans to update the two software programs every six months. "These products provide the utility user with an enhanced ability to sort and select from a large body of information and also ensure that our members have an up-to-date data base on all end-use visual materials, products, and projects," says Greg Lamb, EMU technology transfer administrator.

Although designed as stand-alone products, MEDIABASE and EUCATALOG will also function as part of TICWorkstation, a PC-based software system for data retrieval, manipulation, and on-line communications that EPRI plans to introduce this spring to technical information coordinators at member utilities. ■ *EPRI Contact: Greg Lamb (415) 855-2449*

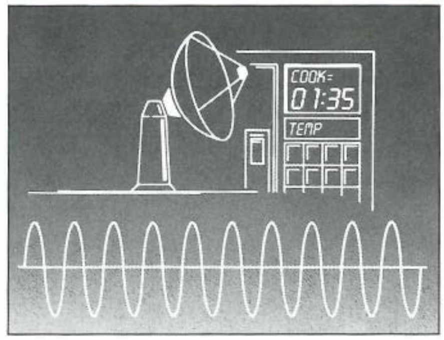
EMF Videos Available

Concerns about possible adverse health effects of low-frequency electric and magnetic fields (EMF) have spurred both an expanded research program at EPRI and an increased interest among the media and the general public. For utilities, these developments have meant increased involvement in EMF issues as research participants, as operators of transmission systems and other equipment that produce EMF, and as institutions answerable to regulators and the public. EPRI, therefore, has produced a series of videotapes to help utilities better understand EMF issues related to human health, the scope and rationale of the Institute's research program, and some of the new techniques and equipment for measuring EMF exposures.

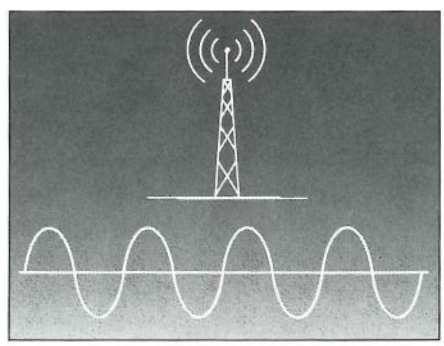
Electric and Magnetic Fields and Human Health (EA87-12) features Leonard Sagan of EPRI in a brief overview of EPRI's research program and the issues it is designed to address. In a video that can be useful to executive, technical, and public information personnel, he defines electric and magnetic fields and explains how some epidemiologic studies seem to relate EMF to human cancer. Sagan then goes on to outline the epidemiologic, exposure assessment, and basic scientific studies that are part of EPRI's overall research response. A second video in the new series, *Electric and Magnetic Field Epidemiologic Studies* (EA87-14), focuses specifically on epidemiologic studies concerning EMF and human health. It features Project Manager Robert Black, who surveys the existing studies and explains how EPRI research can help to fill gaps and increase our knowledge about the relationship, if any, between EMF and human health.



Because accurate measurement of EMF exposure is essential for epidemiologic studies (including occupational studies of utility workers), EPRI dedicated part of its research effort to improving exposure assessment. Health professionals and other personnel interested in exposure measurement can learn about this R&D in *Measuring Electric and Magnetic Fields* (EA87-13). In this video, Stanley Sussman of EPRI describes a series of projects at the Institute to develop portable instruments for measuring EMF exposures, collect human exposure data, and build computer models for projecting EMF exposures. On the same reel, Sussman continues this discussion with *Using the Emdex,* in which he describes using a prototype digital measuring system, the EPRI-developed Emdex, for measuring, recording, and processing exposure data.



As EMF concerns receive more attention, they may well emerge as important political and legal issues facing utilities. Utility professionals involved in EMF issues in these contexts may be interested in *Congressional Hearing on Health Effects of Transmission Lines* (EA87-15). This video consists of excerpts from over three-and-a-half hours of testimony taken on October 6, 1987, by the Subcommittee on Water and Power Resources of the U.S. House of Representatives Committee on Interior and Insular Affairs. The testimony focuses on the possibility of health effects from electric power frequency magnetic fields. Eight witnesses testified, with EPRI represented by Sagan. ■ *EPRI Contact: Susan Rapone (415) 855-2147*



Renewable Energy Systems

Photovoltaic Operating Experience

by John Schaefer, Advanced Power Systems Division

At noon on a clear day only about 1 kW of solar energy is available on the surface of a photovoltaic (PV) panel and only about 10% of that can be converted to usable electricity. Because of the diffuse nature of solar energy, prospective utility-scale PV installations will consist of huge collector areas and large numbers of connections—switches, cables, fuses, contactors, and diodes. For such an installation to be cost-effective, all these connections must be extremely reliable, so much so that they require almost no maintenance to ensure that O&M costs are acceptably low.

It had always been expected that PV systems would be reliable, as they have few moving parts. In fact, PV systems and module designs have been substantially improved since the first line-connected systems were installed. For example, at the 97-kW installation at Natural Bridges, Utah, built in 1980, the module encapsulant leaked from the modules and the modules discolored badly (they continued to operate but at lower efficiency). In contrast, newer modules and cells fail much less often. For example, data from 1987 operation at the Sacramento [California] Municipal Utility District's (SMUD's) 1000-kW PV1 plant indicate a functional module failure rate of less than 1 per 10,000 per year. Most of these failures occur in the connections between modules, not in the modules themselves.

Other difficulties, too, such as ground faulting, diode failures, inverter malfunctions, tracker problems, poor connections, and switch failures, that have plagued PV installations have been eliminated, on the whole, with improved designs and more-careful attention to quality control in manufacturing and installation. So O&M costs can be expected to continue their decline.

The following O&M costs are from sites for which data are available for at least a year.

- SMUD's 1-MW, flat-plate, single-axis tracking site, on-line in 1984: 0.5¢/kWh
- Arco's 1-MW, flat-plate, two-axis tracking site in Hesperia, California, on-line in 1982: 0.9¢/kWh
- Arco's 6.5-MW, flat-plate, two-axis tracking site at Carrisa Plains, California, on-line in 1983: 0.5¢/kWh
- Arizona Public Service's 205-kW concentrator site at Phoenix's Sky Harbor Airport, on-line in 1982: 4.8¢/kWh

These O&M costs include maintenance and repairs but not redesign and modifications to correct initial system deficiencies.

Each of these sites has experienced its own design-related problems. For example, the modules used at the Phoenix site are sensitive to moisture-induced insulation failures and resultant ground faults, with the result that more than 50% of the O&M costs are attributable to the modules. The Phoenix system, an early concentrator design, nonetheless provided data useful in subsequent module redesign, including EPRI's point-contact concentrator module (*EPRI Journal*, January/February 1987, pp. 4–15).

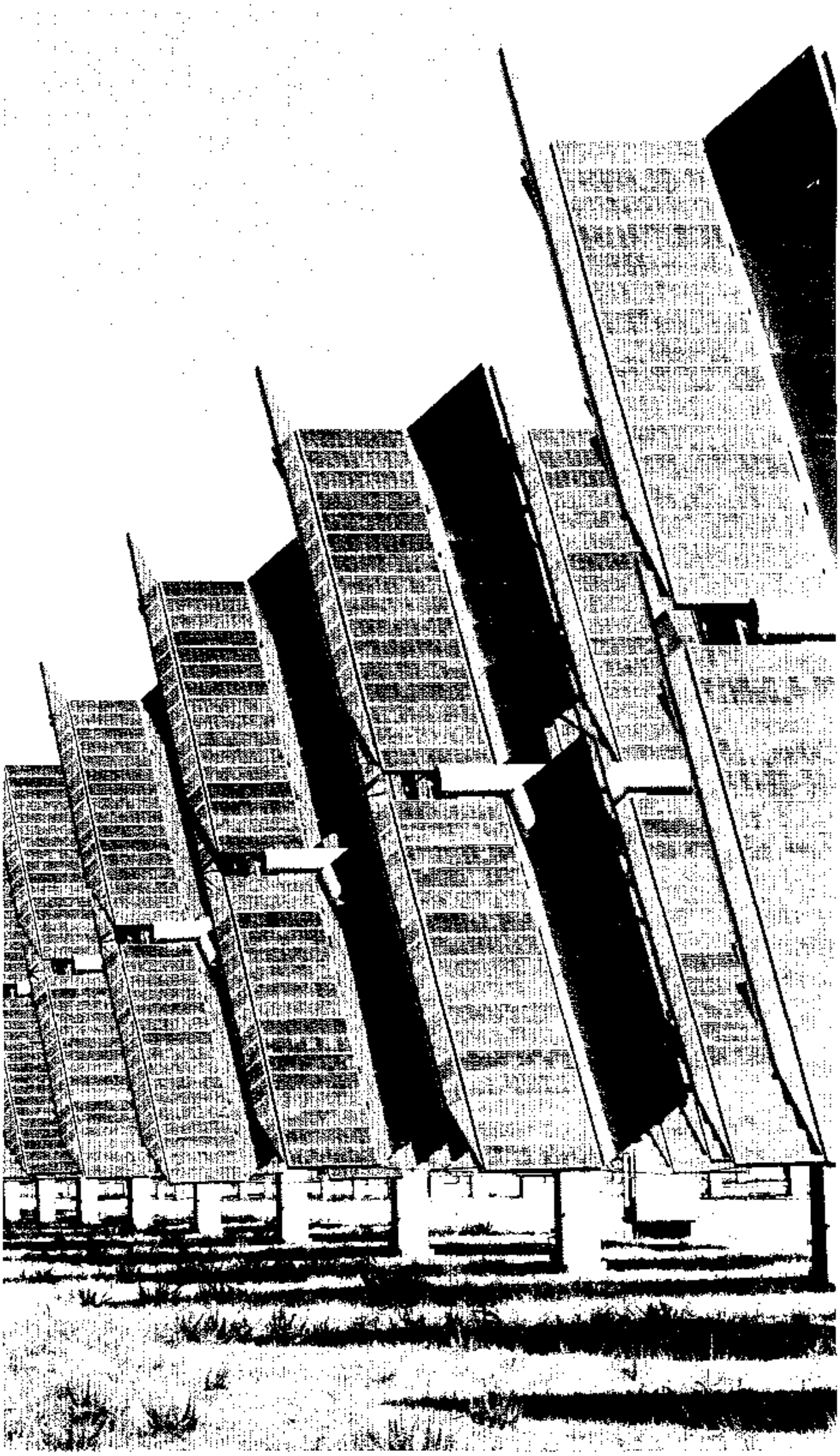
After several years of operation, the inverter at Phoenix grew to be quite unreliable, and it was replaced in 1985. Subsequently, the site operator, Arizona Public Service, noted that whereas the original inverter had been the least reliable component in the system, the new one turned out to be the most reliable. The Sky Harbor plant was decommissioned in December 1987.

Inverter failures have also been a problem at SMUD's PV1 plant, where they accounted for 70% of the O&M costs. This inverter also was of an early design, and improved versions at other sites have demonstrated markedly better reliability.

Ground faults on several PV systems have pointed up system design weaknesses that

ABSTRACT *Photovoltaic demonstration systems are achieving the low operating and maintenance (O&M) costs that are prerequisite to utility-scale installations. Using utility-grade components, newer systems are functioning with O&M costs of about 0.5¢/kWh. Earlier tracker gearbox and module problems have been largely overcome in advanced designs, and component reliability has been steadily improved until it is now consistent with system cost-effectiveness requirements.*

Figure 1 **Problems at PV sites come from unexpected quarters. When panels tracking the sun are close to the ground, rams grazing in the fields attack their images in the concentrating mirrors.**



have since been corrected. Under normal circumstances, a ground fault with a single string's short-circuit current simply takes one string out of service because the blocking diode prevents backfeed from the other strings. But when blocking diodes fail as short circuits, the ground fault current supplied by all other strings grows to many times the string current. Fires have occurred at SMUD and at Sky Harbor with such double-contingency failures. Two solutions have been adopted: the use of hardier diodes and varistors to prevent diode stress, and the installation of fuses rated at the string current to prevent backfeed.

Data from Arco's Hesperia plant (northeast of Los Angeles) reflect tracker difficulties experienced during 1985 that accounted for almost 50% of the plant's O&M costs. Primarily, the problems were gearbox cracks and failures, mainly a result of winds at the site that exceeded expected levels. Reliability, like performance, depends not only on the equipment but also on site characteristics. Again, experience gained from operations at this site proved helpful in the subsequent design of Arco's Carrisa Plains plant in central California, near San Luis Obispo. For one thing, wind loads were considerably lower there, and for another, strengthened versions of the old Hesperia gearboxes were used.

Carrisa Plains exemplifies the PV plant of the future. Inverters there have been reliable, there have been no tracker gearbox problems, and electrical system reliability has been high. Ground faults do occur occasionally in segments 1 through 9, but segment 10, in which an improved module design was used, has had no ground faults since it was put in service in early 1985.

There have been unforeseen difficulties at Carrisa Plains, however. Segments 1 through 9 have concentrating mirrors on each side of the panels, and at sunrise and sunset these mirrors are close to the ground (Figure 1). At those times sheep, which were used at the site to keep the grass down, could see themselves in the mirrors. Now, when a ram sees another ram, he sometimes attacks, with the result that a number of mirrors had to be replaced.

Routine maintenance of PV sites is minimal: changing air filters, lubricating gearboxes, and making calibration checks. Again, however, there have been unexpected problems. For example, bird droppings accumulate on the modules, and cleaning does not appear to be cost-effective. A stuffed owl, posted at the site, failed to discourage birds from perching on PV modules, but occasional blasts from an air cannon sometimes help.

Maintenance costs at the experimental PV installations can be expected to be high because the technology is not well developed; indeed, it is the information being gleaned from these experimental installations that is establishing the basis for advanced technology.

In addition to the four sites discussed earlier, O&M data are available for five others: Lovington, New Mexico (100 kW, 0.3¢/kWh, on-line 1981); Georgetown, D.C. (300 kW, 0.6¢/kWh, 1984); John Long, Phoenix (192 kWh, 0.5¢/kWh, 1984); Austin, Texas (300 kW, 0.4¢/kWh, 1987); and Dallas–Fort Worth Airport (205 kWh, 2.3¢/kWh, 1982). The O&M costs for these nine installations vary from 0.3¢/kWh (Lovington) to 4.8¢/kWh (Phoenix). Although the lowest O&M cost was achieved at Lovington, an early design, the inverters at Lovington have performed so poorly in recent years that the site's output has been low. In general, the lowest O&M costs are associated with plants of more-recent design.

O&M costs at John Long would drop from 0.5¢/kWh to about 0.07¢/kWh if the replacement cost of eight modules, damaged by vandals, had not been included. At Carrisa Plains, the O&M cost (0.5¢/kWh) is an average for all 10 segments; but for segment 10, a more advanced design, the costs are still lower.

The O&M cost at the Dallas–Fort Worth Airport is high (4.8¢/kWh) because it was one of the first concentrators built and it uses a circulating fluid to cool the cells. The cooling system requires pumps, couplings, and hoses, all of which have proved to be high-maintenance components. In fact, most of the O&M cost at this site is attributable to the cooling system.

Similar observations apply to the Phoenix airport system; it reflects early technology design, from which enough has been learned to make possible the design of more-reliable modules.

Indeed, determining O&M costs for these demonstration PV systems makes its most significant contribution not to the analysis of the present systems but to the pool of operating information and experience that will make possible advanced systems for the future. Measured by that criterion, the past eight years' experience with these demonstration systems has proved extremely successful in showing not only that O&M costs can be low but also how systems can be designed to ensure that those costs remain low throughout the operating life of a system.

Radioactive Waste Management

Radwaste Filter Performance Improvement

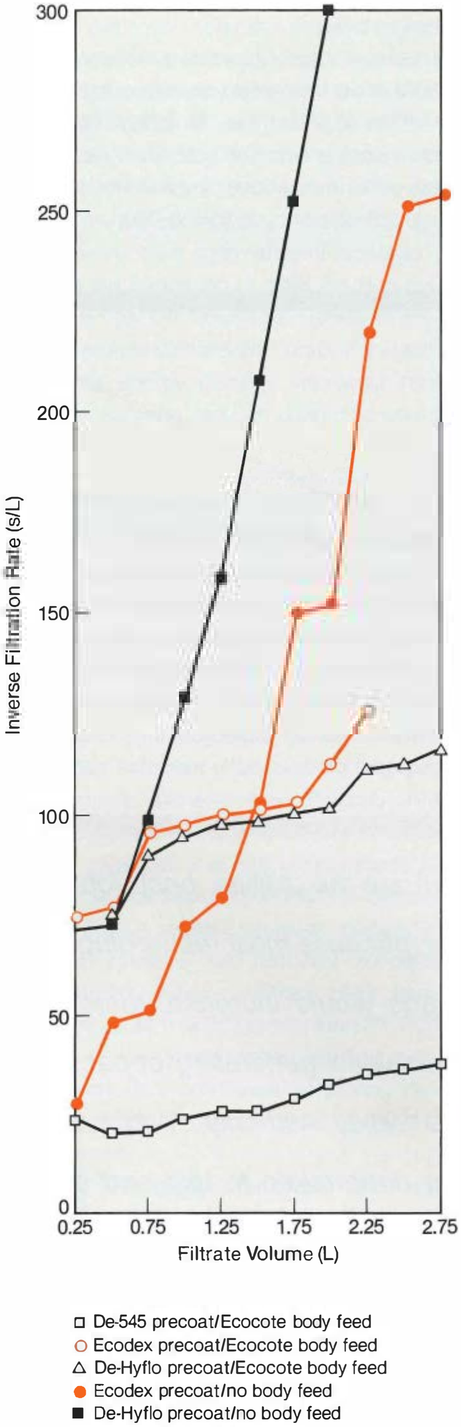
by Patricia Robinson, Nuclear Power Division

ABSTRACT *In BWRs, precoat filter media from the liquid radwaste treatment system constitute one of the largest wet waste volumes produced in the plant. EPRI research on both laboratory and full-scale filtration equipment demonstrated that the use of body feed materials and cationic polyelectrolytes to improve the filterability of BWR waste streams can significantly reduce low-level wastes.*

Economic and political incentives to reduce the volume of low-level wastes shipped from nuclear power plants to burial sites for disposal have spurred many utilities to implement in-plant programs for volume reduction.Others have installed additional processing equipment to further reduce the volume of wastes produced by routine waste treatment. The in-plant methods are normally considered the most cost-effective and are certainly the first to consider before deciding to install additional volume-reduction processing equipment.

By a large margin, the precoat material from a BWR precoat filter generally constitutes a larger volume than the suspended solid contaminants being removed. As a given filter operates, filtered solids reduce flow and increase pressure drop. Therefore, filter performance is stated in terms of gallons of liquid processed per unit volume of precoat material. The testing program described here was aimed at achieving maximum throughput efficiencies for the actual

Figure 1 (left) Test data on filtration times for incremental waste stream volumes show the filterability of the waste stream as indicated by the inverse filtration curves.



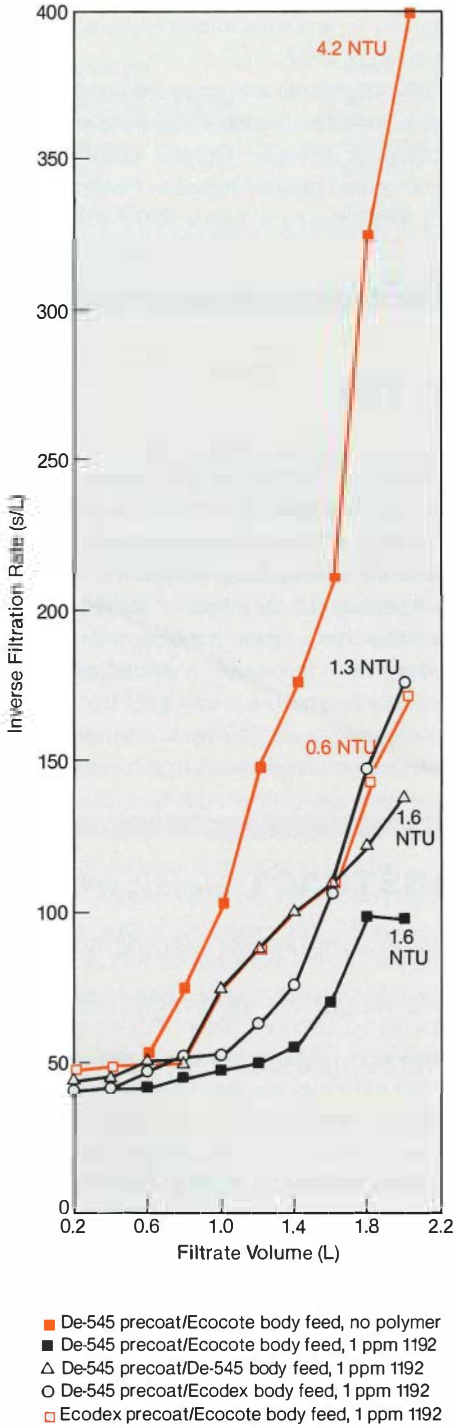


Figure 2 (right) The use of a cationic polyelectrolyte to destabilize colloids and provide interparticle bridging will dramatically improve the filterability of BWR waste streams. High effluent quality shown by nephclometer turbidity measurements (NTUs) also indicates colloid destabilization.

wastewater at operating BWRs.

Dozens of tests using different daily samples of wastewater clearly demonstrated the benefits of using body feed materials. Figure 1 shows that in runs with no body feed, filterability decreased as the run progressed. With body feed, test results showed little change in filterability as the run progressed. Although these results are consistent with fundamental filtration principles, it was important to identify ratios of minimum body feed to suspended solids that would maximize the throughput efficiencies.

Table 1
SUMMARY OF FLOOR DRAIN FILTER TEST RESULTS

Case	Average Run Length (gal)	Average Throughput Efficiency (gal/ft^3)*
No body feed	7700	900
Historical	25,900	1470
Optimized body feed	51,104	5167
Optimized body feed and polymer addition (partially plugged screens)	62,207	8795
Optimized body feed and polymer addition (clean screens)	130,923	11,000

*Gallons of liquid waste processed per ft^3 of filter material.

Other industries have used organic polymers (polyelectrolytes) widely to destabilize colloid systems in waste streams, particularly to achieve water clarity in water treatment processes, but the effect of colloid system destabilization on waste stream filterability has not been investigated before. These tests focused on the effectiveness of cationic polymer use for improving the filterability of the BWR waste stream.

Figure 2 illustrates the dramatic improvement in filterability produced by polymer use. A wide range of wastewater conditions were tested; the tests produced results similar to those in the figure. The testing identified optimal body feed and polymer dosages as functions of the waste stream inlet turbidity.

Full-scale testing followed the laboratory tests, and the results directly mirrored the laboratory test results. Filterability improved dramatically, resulting in significant increases in filter throughput efficiency. Table 1 summarizes the full-scale test results.

On the basis of both laboratory and full-scale test results, investigators reached the following conclusions.

- Laboratory testing is valid for establishing and reducing the size of the full-scale testing program.
- Body feed on the equipment drain filter will improve the throughput efficiency by an estimated 25%. Body feed on the floor drain filter will increase the throughput efficiency by a factor of 3.5.
- DE-545 precoat and body feed materials produce higher throughput efficiencies than Ecodex or Ecocote. Optimal dosages of Ecocote and polymer increase the throughput efficiency by a factor of 6.7 over the historical precoat and body feed used.
- Body feed and polymer operating dosages can be established as functions of influent turbidity.
- The annual volume of waste generated by the floor drain filter would be reduced from 6200 ft^3/yr to 925 ft^3/yr. At \$200/ft^3 total disposal cost, the annual cost saving associated with the above improvement in throughput efficiency is \$1,055,000/yr.

Electric Transportation

Electric Vehicle Testing at TVA

by Gary Purcell, Energy Management and Utilization Division, and Rick Driggans, TVA

ABSTRACT *Electric vehicles (EVs) are the utilities' best potential new market for electricity. Moreover, because most recharging of EVs would be overnight, off-peak loads would increase, thereby improving utilization of the existing baseload generating capacity. Since 1978 EPRI and the Tennessee Valley Authority (TVA) have participated in jointly funded projects undertaken to test and develop EVs, batteries, and various propulsion system components. The purpose of these efforts is to make possible the early commercialization of EVs, at first as special-purpose vans and later as more-general alternatives to gasoline-powered passenger vehicles and light trucks.*

TVA is in a unique position to participate in the development of electric vehicles. As one of the nation's largest utilities, TVA sees the EV as perhaps the last undeveloped load in that utility's service area, which already has one of the highest per capita electricity use rates in the country. With the completion of its nuclear construction program, TVA will have sufficient capacity to support a large number of EVs, especially since most of the load will occur off-peak. Moreover, EVs are quiet and clean, and they permit the substitution of the abundant domestic energy sources used to generate electricity for uncertain supplies of imported oil.

In-vehicle battery testing

In 1981 TVA opened the Electric Vehicle Test Facility (EVTF) in Chattanooga, Tennessee, to support the expanded EV program. This facility includes a chassis dynamometer, a battery test room, a charger test room, charging facilities, and service bays. EVTF is solely dedicated to EV and component evaluation efforts. A one-mile, dual-banked oval track adjacent to the facility is used in the vehicle performance and in-vehicle battery tests.

The principal purpose of the EPRI–TVA project is in-vehicle battery testing (RP1136-27). The temperature extremes and vibration that vehicle batteries must withstand constitute a particularly difficult operational environment. To be effective, testing must be done under similar conditions. At EVTF, battery performance is evaluated in test-bed vehicles that are driven daily. Constant-speed and SAE J227aC-cycle driving range tests are performed each month, and constant-current battery discharge tests are run every 1500 miles (2400 km). Data from such tests are then used to monitor battery performance over the life of the battery.

TVA has tested 10 different battery systems since 1978 (Table 1). The Lucas EV-5T lead-acid battery provided the longest range of the commercially available batteries tested. Its 26,415-mile (42,500-km) life is more than twice that of the closest performing lead-acid battery. In addition, the EV-5T has the most complete module electrical connection and central-point watering systems of any battery tested at TVA. The Eagle-Picher Industries (EPI) NIF 270 nickel-iron battery has provided the greatest range (44,000$^+$ miles; 70,000 km) and life of any system tested; however, nickel-iron batteries are not yet commercially available.

At the beginning of 1988 TVA began testing a new EPI nickel-iron battery in a General Motors Griffon van. This battery features higher energy density, improved central-point watering, and an optimized charging system.

Table 1
BATTERY PERFORMANCE IN TVA IN-VEHICLE TESTS

Manufacturer	Model	Battery Type	Miles Accumulated*	Energy Density (Wh/kg)
Eagle-Picher Industries	NIF 270	Nickel-iron	44,273	50.4†
Lucas Chloride EV Systems	EV-5T	Lead-acid, tubular	26,415	27.8
Hoppecke	3x5PE193	Lead-acid, tubular	12,522	23.7
Exide	XPV-23-3	Lead-acid, flat	8,991	26.3
GM/Delco	DRNZ	Nickel-zinc	7,359	53.8
Johnson Control	EV-2300	Lead-acid, flat	7,299	32.6
Alco	2200	Lead-acid, flat	6,725	24.2
Energy Research Corp.	C-200/5-1	Nickel-cadmium	1,757	36.2†
Gould	GC2-EV200	Lead-acid, flat, sealed	1,466	19.7
Energy Development Associates	—	Zinc-chloride	100	N/A

*Best performance. †Test continuing.

Battery support systems and EV performance

Early testing at TVA revealed the importance of battery temperature control, especially in lead-acid systems. Premature failures of modules situated in low-temperature spots within the battery packs directed attention to the importance of temperature variations across a battery. Because the charge acceptance and discharge capacity of lead-acid batteries are temperature-dependent, it is important that the temperatures of all modules be kept fairly equal. TVA developed and tested several forced-air battery ventilation systems that reduced temperature variations within a battery pack from as much as 38°F (21°C) to less than 3°F (1.7°C). TVA is also testing battery-heating systems that improve cold weather driving ranges by keeping the temperature of the battery elevated.

EV "fuel gages" have also been tested. Many battery state-of-charge meters have been developed, and several have been tested by TVA, but none has proved satisfactory. Consequently, in 1981 EPRI funded the development of a range prediction device (RPD) by the University of Aachen in West Germany. The microprocessor-based device developed in that project gives continuous estimates of remaining driving range on the basis of battery capacity, battery temperature, distance already traveled, and average rate of energy consumption. TVA tests showed that the RPD could be adjusted to give good results for a particular kind of driving, but readjustment was often required if the route was changed significantly and as the battery aged. Also, the RPD would be too expensive, even if mass produced, to use as standard equipment in EVs. However, if the RPD can be integrated into another vehicle component, such as the controller or a battery management system, it may serve as the basis for an economically acceptable EV range meter.

Also in 1981, EPRI and TVA began performance-testing prototype EVs (RP1136-17) because of the need to provide utilities with objective data for making comparative evaluations of EVs. (Data reported by vehicle manufacturers were generally incomplete and unsuitable for this purpose.) The EPRI–TVA performance tests provide information on vehicle acceleration, top speed, energy consumption, driving range on the track and on urban streets, and hill-climbing performance. Detailed testing has been completed on five vehicles. The results of tests at TVA on the General Motors Griffon van were instrumental in its selection for the Electric Vehicle Development Corp.'s van demonstration program.

In 1982 TVA initiated a project to characterize the performance of battery chargers—the connecting link between the utility company and the EV. In addition to harmonic generation and power factor, TVA's charger test determines charger energy efficiency, power output, overcharge, end-of-charge mechanism, recharge time, and electromagnetic interference generation. Test results for four chargers show it is possible to build battery chargers that provide the output characteristics needed by the batteries but still have the low-distortion and high-power factors desired by the utilities.

The most recent EV to be tested at TVA was the CitySTROMer, an electric VW Golf developed by RWE in West Germany. This vehicle has an integrated controller-on-board charger and a lead-acid battery with heating, electrolyte stirring, and central-point watering. Performance testing was completed in the summer of 1987. In the fall of 1987, TVA tested the General Motors proof-of-concept electric G-Van, the U.S.–built successor to the English-built Griffon. In 1988 TVA will test a Chrysler TEVan (modified T-115 minivan body used in the Dodge Caravan), driven by nickel-iron batteries. An extended range EV (XREV), equipped with a small gasoline engine–driven generator to increase its range, will be tested in 1989.

As the EV progresses toward commercialization, a number of government- and EPRI-sponsored development programs are producing new propulsion system components (motors, controllers, transaxles). To determine the improvements in operating efficiency provided by these developments, EPRI and TVA are establishing propulsion system test capabilities at the test facility. A dynamic component assessment center (dc/ac) is being established that will have the capability of testing dc and ac propulsion systems and components under steady-state and dynamic conditions. The dc/ac is due to be operational in 1988.

Future plans

As the EPRI–TVA program enters its tenth year, EV development activities will focus on testing dc and ac propulsion system components, high-energy batteries, and new vehicles produced in the United States by major automotive manufacturers. In addition, TVA and Southern California Edison have entered into an agreement to purchase a high-temperature sodium-sulfur battery system from Chloride Silent Power. This battery will be tested at TVA in a Griffon van during 1989. These efforts will ensure that the EPRI–TVA research will continue to make significant contributions toward the commercialization of electric vehicles.

Energy Storage

The Chino Battery Facility

by Douglas Morris, Advanced Power Systems Division

In October 1987 Southern California Edison placed the concrete foundations for a 10-MW battery energy storage plant at its Chino substation, 50 miles east of Los Angeles. When completed in May 1988, the facility will be the largest of its kind in the world.

The purpose of the plant is to demonstrate the technical and economic feasibility of battery energy storage for load-leveling and energy management applications on an electric power system. Load leveling occurs when off-peak, low-cost power available from other utility systems or Edison's baseload plants is stored and subsequently used during periods of peak demand. Such storage plants are economic when they can be built and operated for costs that can be repaid by the energy cost difference between periods of peak and minimum demand. Other operating modes, such as spinning reserve, can also increase the economic attractiveness of these plants.

Typically, peak power is provided by combustion turbine units with low capital cost and high fuel cost. Depending on the shape of the system demand curve and unit-dispatching costs, energy storage units can reduce the cost of electricity to the consumer by improving the overall efficiency of system operation. Duration of peak power demand has a direct bearing on the feasibility of the type of storage plant—that is, pumped hydro, battery, or compressed air.

Figure 1 shows the major systems of the Chino facility and the interconnection of the facility with the Edison system.

EPRI is providing the power-conditioning system (PCS) to convert power from ac to dc to ac for battery charge and discharge. The International Lead Zinc Research Organization (ILZRO) has loaned over 2000 tons of lead for use in the battery system. Edison has purchased the battery cells and the balance-of-plant equipment and is responsible for the overall construction and management of the project.

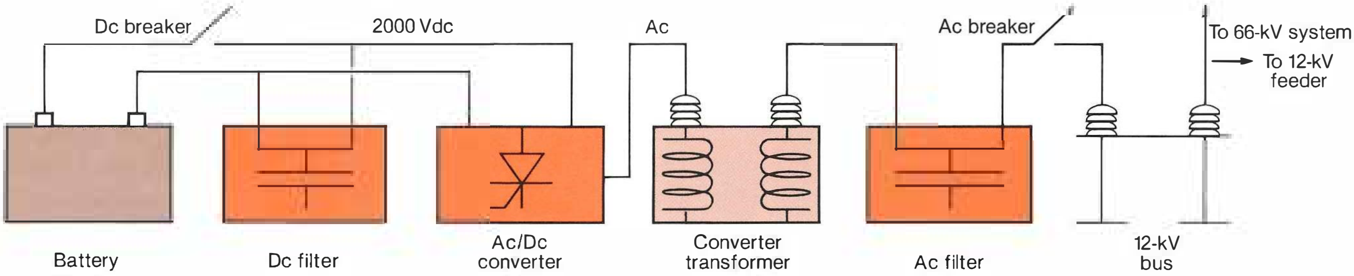
Project objectives and background

Although the primary objective of the facility is to demonstrate load leveling, the following goals are also of great interest.

- Demonstration of operating benefits, such as voltage and frequency regulation, spinning reserve, and improvement in the operation of baseload and intermediate plants
- Validation of design, procurement, and installation/construction costs and determi-

ABSTRACT *Southern California Edison is building a 10-MW lead-acid battery energy storage plant at a site near Los Angeles. The primary objective of this facility is to demonstrate the energy management benefits of storage batteries, and in addition, to investigate the economics of other operating modes. Although the project is a demonstration, the design, procurement, and construction were carried out by normal utility practices. With the plant nearing completion, the project has already achieved the environmental acceptability, short lead time, and capital cost targets projected for lead-acid battery energy storage systems.*

Figure 1 Major components of the Chino energy storage system. Chino receives power from the 66-kV transmission system that feeds other 12-kV loads connected to the substation.



nation of operating and maintenance costs

▫ Introduction to a utility market of a new modular, environmentally acceptable storage alternative

▫ Development and testing of instrumentation and devices suitable for economically monitoring large battery systems

▫ Identification of design and construction methods that would reduce the overall cost of battery energy storage facilities up to a range of 100 MW

Battery energy storage for utility dispatching has been the subject of several EPRI studies for the past 14 years. The concept is not new, and lead-acid battery technology has not changed significantly in many years. In 1985 a series of events suggested that lead-acid battery plants have potential economic feasibility. Several factors, such as the following, played a role in the decision to fund the demonstration.

Storage can improve the use and efficiency of the electrical supply system and reduce the effect of independent power producers by effectively integrating their generation with the customers' demands. In addition, storage can complement a load-management strategy, and because of its fast response, it can ensure continued high reliability of service to the customer.

Energy storage also provides substantial economic benefit when used in operating modes other than load leveling, such as spinning reserve. Studies using improved analytic techniques for system studies showed potential economic benefits approaching $500 per kW.

Legislation had been passed preventing the use of lead additives in paint and automobile gasoline, reducing the price of lead by about a factor of 2.

Advanced battery design and development, such as sodium-sulfur and zinc halide, have evolved more slowly than anticipated.

On average, utility system load factors have steadily declined to about 60%. (This factor is the ratio of the average load to peak demand.)

DOE- and EPRI-funded research beginning in 1975 had resulted in a deep-discharge lead-acid battery cell of long life. Independent tests of this cell suggest a potential life of 4000 cycles and 15 years. A similarly funded effort at the Battery Energy Storage Test (BEST) Facility operated by Public Service Electric & Gas (PSE&G) had demonstrated the successful integration and operation of a 500-kW lead-acid battery system.

EPRI studies on facility design have identified ways to minimize balance-of-plant costs.

In addition to the above factors, battery systems have some unique attributes as storage facilities. They are environmentally acceptable and can be located near loads and in existing suburban substations. Thus, transmission losses are reduced, and sites are readily available. The battery facilities are modular, reducing engineering costs for individual sites, and have a short lead time, which minimizes the cost of capital. These last two features allow utilities to be responsive to increasing load without having to overbuild to achieve economy of scale.

Battery systems can be very responsive to changes in demand. The Chino facility can swing from a 10-MW discharge to a 10-MW charge in about 16 ms. An 8.5-MW battery energy storage plant operated by the West Berlin utility, Berliner Kraft und Licht, has been helping to achieve a frequency regulation tolerance of ±0.1 Hz for that utility since November 1986. One major objective of the Chino facility will be an investigation of operating modes that exploit the battery system's fast response.

In mid 1985 EPRI solicited its members for one utility to host a battery energy storage demonstration plant. Fourteen utilities responded and provided EPRI contractors with their operating data for systems analysis to determine the compatibility of a battery energy storage facility on each system. Edison had been independently studying energy storage as a way to purchase low-cost power from other sources during minimum load conditions on its electric system. Because Edison was the first utility to commit to building a large demonstration plant, it was awarded about $800,000 worth of lead from ILZRO for the construction of the battery and the 10-MW PCS sponsored by EPRI, which cost about $1.7 million.

Facility design

The Bechtel Group was conducting an EPRI study to develop the design and cost of a generic battery facility when Edison elected to proceed with the demonstration plant. The utility hired Bechtel to seek competitive bids for the battery system and to develop a preliminary design for the Chino site. In addition, Bechtel sought bids for the PCS on EPRI's behalf.

The Bechtel work was completed by September 1986. At that time Edison issued a request-for-quotation for an engineer to develop the final design and procure all buildings and balance-of-plant systems. Edison provided a budget of $10 million and an ambitious schedule. This schedule required that the engineer's scope of work be completed by April 1987. Edison then planned to select the general construction engineer by competitive bid and have the facility operational by April 1988 (i.e., 17 months after selecting the engineer).

Edison selected United Engineers & Constructors (UE&C) of Denver, Colorado, as the facility engineer. EPRI then contracted with UE&C to expedite the PCS procurement and ensure its proper integration with the remainder of the facility. EPRI also selected UE&C, as the engineer of record, to document the experiences and lessons learned on this project for the utility industry.

A battery energy storage plant has very few subsystems, and because the subsystems are factory built and tested, engineering and construction are rather straightforward. There are only three major subsystems: the battery, the PCS, and the facility monitoring and control system (FMCS). Auxiliary systems include the fire protection system, battery watering and air systems, HVAC, and building cooling.

The Chino facility is located on a 26-acre substation that has been in operation for about 75 years. The substation was initially a hub in Edison's system between hydro plants in the San Bernardino area and coastal communities. In 1939 the first power from Hoover Dam was distributed to southern California through the substation.

One and one-half acres were required for the battery energy storage plant. Because of the rectangular configuration of the site, two standard-size prefabricated buildings were chosen to house equal amounts of the battery system (Figure 2). The PCS and control room are located in a central third building to allow battery string cable impedance to be as equal and symmetrical as practical.

As a safety precaution the two battery buildings have an 18-in-high (46-cm) curb that provides a containment volume of 233,000 gal (882 m^3) of water. The worst-case scenario of a sustained short circuit has an estimated spill volume of 100,000 gal (379 m^3) of fire protection water and the acid content of 400 cells (5000 gal; 19 m^3) In the event of a large spill, a licensed hazardous-waste contractor would neutralize the acid in place and pump the mixture into a truck for disposal.

The battery buildings have outside air circulated to change the building air volume 12 times an hour to control the accumulation of hydrogen to less than Occupational Safety and Health Administration (OSHA) limits. Battery cooling is mainly by natural convection of the cells.

The battery system

Edison selected Exide Corp. of Yardley, Pennsylvania, to be the battery supplier after evaluating six international bids. Exide began load-leveling, lead-acid cell cost, and design studies under an EPRI contract in 1975 and subsequently developed a deep-discharge, lead-acid battery cell for load leveling under a DOE contract. Twelve cells were tested at the Argonne National Laboratory for life and performance, including operation in a high-temperature environment. Six of the cells were tested at 50°C and achieved 2300 cycles, which is considered by some researchers to be roughly equivalent to 6000 cycles at ambient temperature. The cells had greater than 108% of rated capacity when they were taken off test.

Deep-discharge lead-acid batteries are similar in concept to automobile batteries but still require the regular addition of water to maintain the electrolyte level. The cells are also much larger, in the range of 16 in long (41 cm), 15 in wide (38 cm), and 23 in high (58 cm), weighing 580 lb (263 kg) per 2-V cell. Each cell has a five-hour capacity of 6.2 kWh and a rated capacity of about 5 kWh at a four-hour discharge rate and at 80% depth of discharge. The cells contain 17 positive and 18 negative plates. When the cells are new, battery efficiency (dc/dc) for a charge/discharge cycle is 78%.

Six battery cells are mounted on a steel frame to form a 12-V module for ease of transportation and installation. The modules are then stacked on two-tier racks. Four rows of racks are connected in series to form a battery string of 1032 cells, which establishes a nominal bus voltage of 2000 V_{dc}. Altogether, 8256 deep-discharge, ¼-ton lead-acid cells will store 40 MWh for four-hour daily discharge. The racks and frames are designed to withstand seismic UBC Zone 4 conditions.

The battery system requires two auxiliary systems for efficient operation; one is the air agitation system, the other supplies water to restore the electrolyte level. The air agitation system consists of a packaged compressed-air system supplying air to tube manifolds arranged along the racks. Tubes, connecting the manifolds to each cell, convey air to a vertical tube in a corner of the cell, allowing air to be bubbled down the tube. This action is sufficient to stir the acid electrolyte and prevent stratification, thus increasing the cell's operating efficiency and life.

A similar supply system provides water from a central tank to each cell. Manually operated valves provide water to sections of the racks in turn. A water valve mounted in the flame arrester, located in the cell top, cuts off the water supply to the cell when a predetermined level is reached.

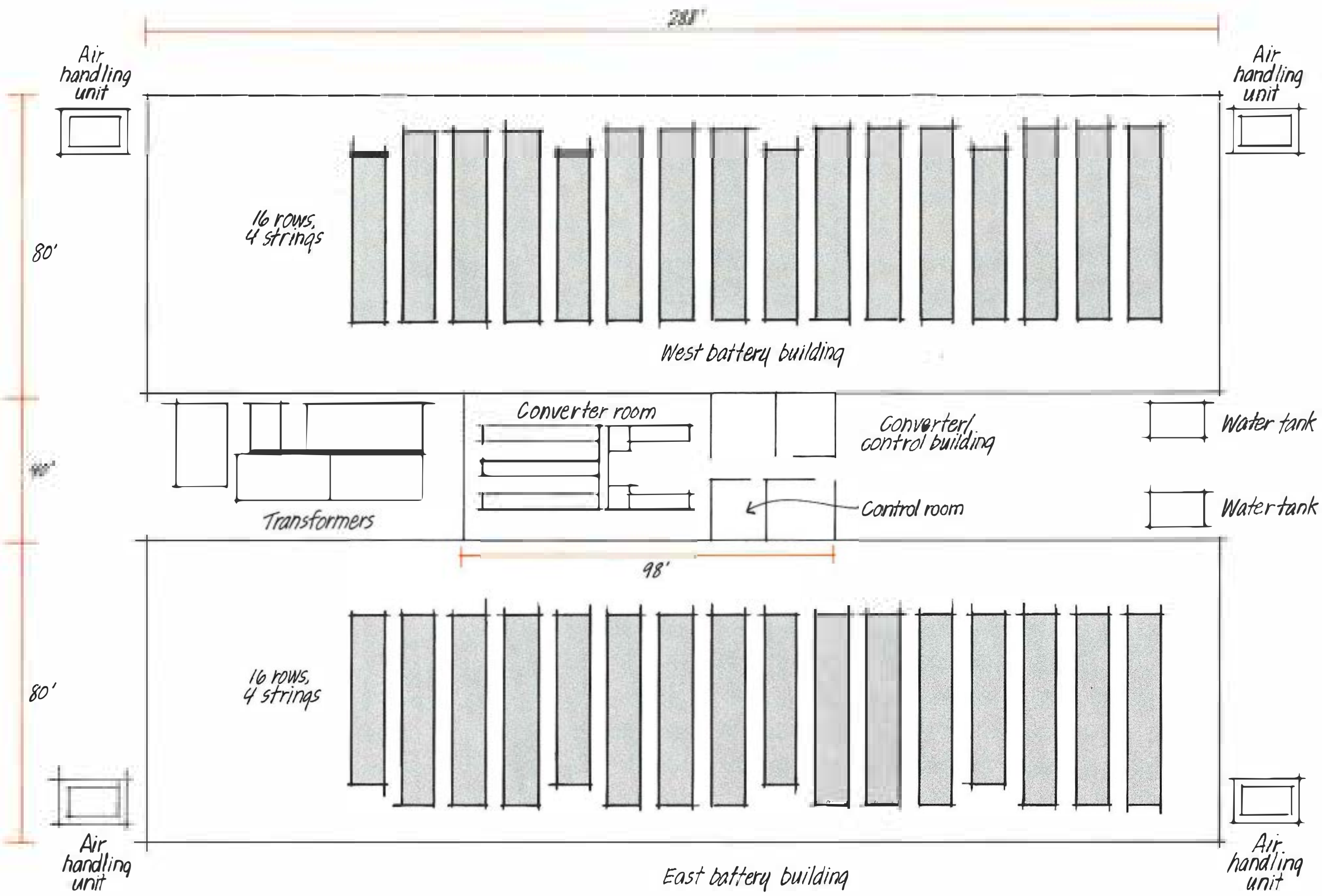
In addition to hydrogen, other gases (metallic hydrides formed from the lead-alloying constituents) are vented from the cell during the final stages of the recharge operation. These gases are captured by a filter canister filled with activated charcoal and mounted within the flame arrester on each cell.

Power conditioning system

Nine vendors responded to the RFP for the PCS, which Bechtel issued on EPRI's behalf. General Electric's Drive Systems Division of Salem, Virginia, was selected.

The General Electric equipment is a self-commutated, voltage source, 18-pulse

Figure 2 **General arrangement of the lead-acid battery energy storage facility at Southern California Edison's Chino substation.**



stepped-wave converter that relies on gate-turn-off (GTO) thyristors for switching. This design provides the capability to control reactive power at Edison's 12-kV Chino substation by ± 10 MVAR. In addition, the converter can continue operating through line voltage swings and can suppress the harmonic output of the ac voltage to the seventeenth harmonic.

The PCS rectifies ac power fed from the 12-kV line to 2000 V_{dc} to charge the batteries. During the battery discharge mode, the PCS inverts the stored dc power to ac to return power to the grid. The round-trip PCS efficiency is about 95%.

An integrated microprocessor controls the flow of power, protects the PCS from fault currents, charges the batteries automatically, and diagnoses the operating condition of the PCS.

Experience to date

UE&C completed the final engineering design, procurement of buildings, and balance-of-plant equipment by May 1987, a five-month task. Edison issued a quotation request for the general construction contract in the same month and made the award to Gulf States, Inc., of Houston, Texas, in July 1987.

The schedule was delayed when the City of Chino was backlogged in issuing permits for three months because of the tremendous building boom in that area. Construction began in October 1987, with the estimated completion date slipping only a month to May 1988, an elapsed time of 18 months from conceptual design. Construction is expected to take nine months.

The large size of the battery order has forced Exide to manufacture the cells over about a 12-month period. The batteries were put on a float-charge in a warehouse until the battery buildings were completed, at which time shipment of the cells in modules took place. Shipment was by truck from Richmond, Kentucky, to Chino, California.

The PCS is a new design but based on similar equipment used in variable-speed drives and uninterruptible power systems. Parts were ordered following design completion, and subassembly started in August 1987. The equipment was assembled for a full-system factory test in early November. General Electric conducted a six-weeks' test at full voltage–low current and at full current–low voltage. The PCS arrived at Chino in early February 1988.

No environmental impact statement was required for the Chino facility—only hydrogen will be released because filters capture the rest of the gases. The curbed building design eliminated the need for underground tanks and minimized the underground and foundation work to that required by sewers and storm drains. The one-story buildings are lower than the existing substation building, and emissions or perceptible noise levels are not expected to occur at the site boundary.

With all the equipment purchased and construction under a fixed-price contract, the first-of-a-kind battery energy storage plant will cost about $13.5 million, land excluded. This value is very close to the original estimate. Because of the knowledge gained in building the Chino plant, other plants will cost less as a result of reduced engineering and balance-of-plant costs. The major plant component cost is for the battery cells. Cost reductions in that area will depend on mass production techniques resulting from increased demand for utility energy storage batteries.

A two-year test and evaluation program will be designed and conducted to demonstrate to Edison and other interested utilities the cost and benefits of battery energy storage in various operating modes. The future of battery energy storage in the United States will depend on the success of this project and the acceptance by utilities of battery energy storage as an economically viable, short lead time, and modular technology. Applications of the technology are limited only by the creativity of the utility operator and planner.

Environmental Effects

Electric and Magnetic Field Exposure Assessment

by Stanley S. Sussman, Environment Division

ABSTRACT *Studies of possible links between cancer and exposure to electric and magnetic fields have been flawed by an insufficiency of data on the intensities of the fields usually encountered in residential and occupational environments. To facilitate field-intensity data acquisition, EPRI developed Emdex, a small instrument worn on the person to measure and record field strengths for subsequent analysis and display on a PC. In addition, a new version of the EXPOCALC computer program will soon be released. Capable of simulating both electric and magnetic fields, EXPOCALC 2 will permit more general characterizations of the electric and magnetic fields around utility transmission lines.*

The biologic and health effects of electric and magnetic fields have been studied since the 1960s. Until recently the emphasis in these studies was on the effects of electric fields, particularly those associated with high-voltage transmission lines, because they were thought the more likely to potentially produce biologic effects. A significant number of studies with humans, animals, and plants found no evidence of effects that could be considered harmful to human health, however, even though the field strengths used were usually significantly higher than would ordinarily be encountered.

In several post-1979 epidemiologic studies of childhood cancer, interest shifted from electric fields to magnetic fields associated with high-current-capability utility wiring in proximity to homes. Occupational studies have also dealt with increased risk for workers whose jobs are thought to expose them to higher-than-average field intensities. The results of these studies have been uncertain and inconsistent, but they have nevertheless directed attention to the possible role of magnetic fields in the occurrence of some cancers; thus, more studies are now in progress or are being planned under the sponsorship of EPRI and others.

Measurements of the magnetic fields to which subjects in the earlier studies were exposed were very limited. In the residential studies, for example, a wire classification scheme was used as a substitute for current-carrying capability, and an exposure metric was developed that combines the wire classes with distances from homes. Indeed, very little is known about field levels in homes and places of work. Whereas the earth's steady magnetic field is about 500 mG, the average background levels of

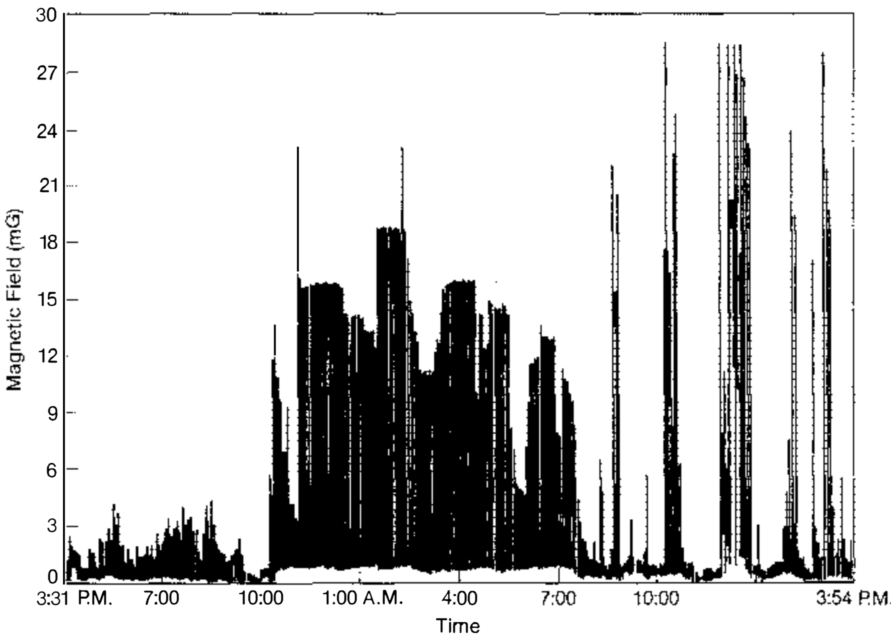
60-Hz fields in U.S. homes are typically less than 5 mG. However, they vary substantially over space and with time. The sources of these fields include, for example, external utility lines, appliances, and household wiring. However, their individual contributions to the total field are not well understood. Exposure assessments, which require not only information about the field intensities but also information about human activity patterns, are therefore difficult to obtain.

There are two complementary approaches to obtaining exposure assessments: field-strength measurements and computer simulations. Measurements provide data for specific cases, but a complete characterization through measurements alone would be prohibitively time-consuming and expensive. Instead, the limited data and known physical principles are used to build models that can extrapolate measured exposures to a broad variety of environments and situations.

Personal exposure measurements require instruments that are compact and lightweight but capable of monitoring and recording data over extended periods. Using recent developments in high-performance microcircuit technology, Enertech Consultants and General Electric developed the Emdex (electric and magnetic field digital exposure) system under EPRI sponsorship. The Emdex prototype is 6×4×1.5 in (15×10×4 cm) and weighs about 14 oz (398 g). The instrument contains field-sensing coils, a signal processing and control board, and a computer with a 256-K CMOS RAM memory. Three of the coils are mounted orthogonally for independent measurement of the three axes of the magnetic field; a fourth senses rotational motion in the earth's magnetic field. Two ranges of magnetic field strength (0–25 and 0–250 mG) are provided.

A conductive-cloth sash is used with the Emdex instrument for measuring electric fields. The signal from the sash is fed into a port in the Emdex unit, and field strength is read on one of three ranges with full-scale readings of 112.5, 1125, and 11,250 V/m. Future versions of Emdex will incorporate autoranging (to eliminate the range switches) and capability for measuring higher-strength magnetic fields. Power is provided by a 9-V battery.

Figure 1 Emdex-recorded variations in magnetic field strengths to which a child was exposed throughout a day. The high levels at night show the effects of an electric blanket. Most of the other intensity spikes reflect field strength changes encountered along the way to and from school.



In addition to the hardware unit, the Emdex system includes PC-based software with several programs. A setup program allows the user to specify the data collection rate, which can be up to one sample per second. The rate determines how long data can be acquired before exceeding the memory capacity of the internal computer. Once the data are collected, they are transferred to the PC for analysis and display.

Several options are available for organizing and plotting results. All tabular and graphic output can be sent to a printer for hard-copy records. Figure 1 is an example of a time record of magnetic field exposure. The wide variations in short-term exposure shown in the figure suggest that using either nominal values obtained from single-point measurements or exposure surrogates may not be adequate.

As the first in a series of personal exposure models, the EXPOCALC computer software package provides a method for simulating exposure to transmission line electric and magnetic fields during a variety of human activities. Version 1 of EXPOCALC, which simulated only electric fields, has been available since 1986 and has been tested by over 100 utilities. The newly developed EXPOCALC 2 includes a magnetic field module; it has also been improved in several other ways.

EXPOCALC uses a systems activity model to study the interactions between the activities of persons and their physical environments. This model is combined with engineering-based methods for calculating the electric and magnetic fields associated with the voltages and currents carried by transmission lines. The result is an easy-to-use, PC-based program that is useful in characterizing exposure for a variety of transmission line design options, in studying field reduction or abatement strategies, and in better equipping individuals to discuss issues related to electric and magnetic fields.

EXPOCALC is executed through a series of nested menus that guide the user, beginning with a main menu from which electric field analysis, magnetic field analysis, or both can be selected. An options menu offers the choice of a complete analysis or individual program selections. A program menu presents the individual program choices if this option was chosen previously.

Data entry is organized into screens that guide the user through the analysis. The data needed to specify the input conditions are a description of the study area or path, transmission line design parameters (such as configurations, heights, and ground clearances), activity factors, time budget information, and a definition of field ranges or bins (needed for field contour plotting and tabulation of exposure results). Plots of the study area and the line cross section are also available. After the data entry is completed, the second program module computes the field values at all points in the study area. A plot module draws equal-field magnetic force contours for the area. The final module provides the exposure data by combining the previously calculated field values with data on human activity.

Demand-Side Planning

Customer Preference and Behavior

by Larry Lewis, Energy Management and Utilization Division

ABSTRACT *EPRI's long-term customer preference and behavior project is one of several efforts under way to help the utilities identify and understand the market potential of new technologies and demand-side management programs. The project's market research has already developed software the utilities can use to categorize residential customers on the basis of like attitudes toward a set of study-developed needs/benefits criteria. By providing insight into customer needs, perceptions, and decision-making processes, this research will make it possible for utilities to predict the level of customer participation in proposed demand-side programs.*

Electric utilities use demand-side management (DSM) programs to shape loads, to control costs, and to better serve their customers. The effectiveness of these programs depends, of course, on customer participation. To develop demand-side programs that ensure customer acceptance, utility planners must (1) consider how their customers perceive utility programs, (2) identify and characterize target markets, (3) determine how customers make end-use purchase decisions, (4) define factors that affect participation in utility programs.

EPRI's customer preference and behavior project is one of several sponsored by the Demand-Side Planning Program (RP2671). Its purpose is to help member utilities develop and promote DSM programs. It will demonstrate how market research techniques can be used to provide vital information needed in developing programs to meet load-shape objectives and to respond to customer needs and preferences. The project will provide the utilities with decision models, a national data base, guidebooks, case study examples, and experience gained from model applications.

This research project comprises three activities: marketing research and modeling, demonstrations and applications, and communications. The marketing research and modeling activity has two goals: to develop a customer decision framework and a family of models that can be used to estimate customer participation in DSM programs; and to develop a national reference data base of customer needs, beliefs, and preferences for use with the models.

Marketing research and modeling

This activity will produce the following.

- Needs-based segmentation in which customers are grouped by energy needs and benefits and then correlated with demographic segmentation
- A national reference data set that quantifies customer needs and preferences for various customer segments
- A choice model that can be used to estimate customer participation in a DSM program with various specific attributes

These products derive from the National Residential Survey that covered housing stock and appliance consumption; household decision making; customer attitudes, needs, and perceived benefits; conjoint trade-offs among DSM options; media use and communication; purchasing habits; and family composition.

The survey instrument included a wide variety of modules: needs/benefits associated with electric appliances and their use; housing stock and appliance stock; household composition and demographics; appliance purchases; energy use and conservation behavior; and the purchase and participation likelihood for competing DSM products and programs.

Three general categories of needs/benefits, comprising nine individual items, were defined: costs and use, perceived benefits, and concerns. The costs and use category contains electricity conservation/budgetary concerns, search minimization, and personal control; the perceived benefits category contains high-tech enthusiasm, convenience, and comfort; and the concerns category contains appearance, safety, and task-versus-area energy use. After the categories were defined, the survey respondents were put into groups of like attitudes toward the nine needs/benefits, which in turn led to the partitioning of the residential sector into six needs/benefits segments. The segments, and the percentage of residential users they account for nationally, are as follows: appearance conscious (18%), pleasure seekers (22%), resource conservers (17%), lifestyle simplifiers (17%), hassle avoiders (13%), and value seekers (14%).

A needs/benefits segmentation scheme was used because it reflects better how one analyzes energy choices. The most common type of segmentation schemes are demographic or life-cycle stage. However, the project team believed that for energy use, needs/benefits would be superior. Indeed, when the needs/benefits segments were matched to demographics, it was clear that several segments with very similar demographic characteristics have diametrically opposed needs/benefits results. This use of needs/benefits provides a more direct link between targeting and program positioning. If the planner used only demographics to predict program participation and appropriate message and media preferences, the results would very likely fall far short of projections. Only needs/benefits segmentation can give the complete picture of the customer's energy decision-making process (Table 1, page 54).

The National Residential Survey used a 48-item questionnaire; however, for application by member utilities, the questionnaire was reduced to 20 items that reliably classify residential customers into one of the six needs/benefits segments. A software version of the 20-item instrument is now available; it is provided with a discriminant function that uses the answers to the questions to categorize respondents according to the six segments. Any utility can use this software to group its customers according to the needs/benefits segments. This software, CLASSIFY can be used either in a

Table 1
RESPONSES TO NEEDS/BENEFITS BY RESIDENTIAL SEGMENT

	Residential Segment					
Needs/Benefits	Appearance Conscious	Hassle Avoider	Resource Conserver	Pleasure Seeker	Lifestyle Simplifier	Value Seeker
Concerns						
Appearance	+	■	●	+	●	●
Safety	+	●●	■	+	■	●
Task-vs-area energy use	●●	■	+	+	■	●
Costs and use						
Conservation/budgetary	●	●	+	+	●	■
Personal control	■	+	●●	+	●	■
Search minimization	■	+ +	●	■	■	●●
Perceived benefits						
Comfort	■	■	■	+	●●	■
Convenience	■	■	+	+	●●	■
High-tech enthusiasm	■	●	■	+	●●	+

■ average
\+ greater than average
\+ + much greater than average
● less than average
●● much less than average

batch mode or interactively. Over 150 utilities requested copies of the CLASSIFY software and support materials in the first three months of release.

Following the segmentation activity, the marketing research and modeling project developed a choice model that allows utilities to predict customer acceptance of DSM programs by needs/benefits segments. The choice model is based on models used in consumer goods research but suitably revised for this utility application. A result of this initial research was a customer energy decision-making framework, which was then used to develop the residential preference model (EPRI EM-5217). The preference model estimates customer participation in a particular program design by needs/benefits segment.

The residential preference model, which will be marketed by EPRI under the name PULSE, is now being beta-tested by six utilities. The PULSE software makes it possible to estimate appliance program shares for particular residential DSM programs on the basis of user-specified appliance program features in a user-friendly environment.

The user first selects one of eight DSM programs used in the National Residential Survey: clothes dryer rebate, water heater rebate, central air conditioner rebate (3-ton only), central forced-air heating system rebate (with three weather zone options), rate alternatives, and air conditioner load control. Next, the user chooses alternatives for the program selected. For example, for clothes dryer rebates the user can specify fuel type, retail cost, brand, temperature setting, presence or absence of a moisture sensor, operating cost per load, rebate source (manufacturer or utility), and installation cost (included or not). The resulting shares are estimates of the percentage of customers choosing each alternative.

Commercial sector market research and modeling began during the summer of 1987. Because the energy decisions of commercial users are different from those of residential users, the commercial sector research design is also different. The research will begin with an in-depth review of the commercial decision-making process to determine who makes energy decisions in the commercial sector, how the decisions are made, how economics are considered, how decision making varies with end-use type, and how capital investment and operating and maintenance costs are traded off. To address these questions the project team is interviewing commercial users who have recently made energy decisions in each of three broad DSM categories: packaged cogeneration (either capital investment or shared savings programs); lighting programs (either interior or exterior); and rate incentives (contracted or time-of-use).

The marketing research and modeling team completed an analysis of customer awareness of demand-side programs resulting from utility advertising to quantify customer awareness of demand-side programs for use in the PULSE model as refinements to market share estimates. After reviewing the data from more than 35 utilities, the project team determined that because of the wide variety of program types, advertising media and budgets, and methods of accounting used by utilities to track advertising awareness, it is inappropriate to develop parametric statistics on the basis of the data provided. Nonetheless, the data can serve as general guidelines for residential customer awareness of DSM programs, and the project team estimated that utilities can use a base level of 20% awareness for a particular DSM program when using the PULSE software in the absence of specific data from their service area.

Demonstration and applications

The objective of this activity is to conduct customer preference case study demonstrations, applying the data bases and models from the CP&B project, and to design and test-market DSM programs under real conditions. This activity will make it possible to fine-tune the models, identify exemplary marketing programs, and validate the project approach.

Case studies are under way at the following utilities.

- St. Joseph Light & Power Co.: testing a residential dual-fuel program
- Carroll Electric Membership: testing a

builder's water heater give-away program

- New York State Electric & Gas: testing a residential thermal storage program
- Blue Ridge Electric Membership and North Carolina Alternative Energy: testing a residential dual-fuel program
- Northeast Utilities Service: testing a commercial lighting rebate program
- New England Electric System: testing a residential load control education program

The original intention of the St. Joseph Light & Power study was to promote add-on heat pumps. After setting up focus groups and doing other market research, however, the team realized that add-on heat pumps would not be well received by St. Joseph's customers. Instead, the research pointed toward supplemental heating programs. The next step was to meet with utility management and advertising account executives to provide guidance on translating market research findings into a media campaign. Appropriate trade ally activities and related market-tracking activities to obtain sales volume information on supplemental heaters during the promotional period are being developed.

The study at Carroll centered on a water heater give-away program to build electric load. The team conducted two residential focus groups, and on the basis of the findings, is preparing a 400-point survey of residential customers with oil and gas water heaters. The results of this survey will be used to develop positioning and targeting strategies for Carroll's give-away program.

The New York State Electric & Gas case duplicated the choice-modeling techniques used for the PULSE model in a previous survey to test different program configurations, including rebate amount and types of media and message.

The pilot program for testing residential dual-fuel applications at Blue Ridge Electric and North Carolina Alternative Energy will begin after several critical implementation issues have been resolved. While Blue Ridge has been completing a strategic marketing plan, the project team has been investigating the benefits and costs associated with a conjoint study for that utility's dual-fuel program and preparing inputs to a questionnaire for use in targeting potential dual-fuel customers. Detailed program implementation planning began last October.

Northeast Utilities is hosting the first commercial case study, which is concerned with lighting rebate programs. Two focus groups were used. One represented customers who had participated in a lighting rebate program and had received rebates; the other represented nonparticipants. Nonparticipants were difficult to recruit because most either were renters or had too small a lighting load to make the investment worthwhile.

The focus group report is in preparation; it will be reviewed by and discussed with Northeast Utilities, and a decision will be made about further action.

New England Electric System wants to test the effectiveness of educational campaigns in increasing customer participation in load-management programs. The project team will conduct in-depth interviews of families in an effort to better understand the changes that customers have made in response to New England's time-of-use rate experiment. Using data collected from the survey and load-shape data that the utility has been collecting, a phase 1 summary report describing methods, findings, and conclusions will be prepared. The next case study phase will involve a duplication of the rate conjoint design used for the national residential survey. This survey will be administered to up to 400 respondents in the Narragansett service area. The project team has also initiated or reestablished contact with several utilities that are potential hosts for commercial sector case studies, including San Diego Gas & Electric, Baltimore Gas & Electric, Wisconsin Electric, and Florida Power & Light.

Communications

The communications activity will combine and present those results of the other two activities (market research and modeling; demonstration and applications) that can be used directly by utilities guidebooks, reports, computer software, workshops, and data bases. The customer preference and behavior project is unique in that it has a discrete communications activity and in that communications products will be released throughout the project's tenure.

The communications activity has been a busy one over the last year. Presentations were made to more than 40 organizations (utilities and others), and a number of regional workshops were held in conjunction with conferences scheduled by regional electric utility marketing organizations.

The purpose of the workshops is to instruct utility planners on the scope and usefulness of the residential preference model PULSE. The workshops are sponsored by EPRI in cooperation with utilities and governmental agencies, and three have already been held (Hartford, Birmingham, and San Diego).

The residential preference model PULSE is being beta-tested at six utilities and is being demonstrated at the workshops and at other industry meetings. A marketing planning primer, which is nearing completion, will provide background for making marketing plans that are specific to the utilities and will explain how market research results from the project should be incorporated into utility market plans. In addition, CLASSIFY is now available to the utilities, and a project newsletter will be published to report project accomplishments.

The most encouraging aspect of the research and activities of the project has been the utility industry's continuing interest and the wide application of customer preference and behavioral data to other EPRI projects. There is new emphasis in the electric utility industry on understanding and considering the needs and perceptions of the customer. This project will continue to produce market research insights and techniques that will significantly increase the probability that utility demand-side programs will achieve the wide participation necessary to ensure maximum benefits to both customer and utility.

New Contracts

Project	Funding / Duration	Contractor / EPRI Project Manager
Advanced Power Systems		
Data Correlations and Performance Analyses, Gas Turbine Instrument Tests (RP2102-7)	$201,800 35 months	Pratt & Whitney Aircraft Group/*L. Angello*
Coal Mining and Transportation Support (RP2525-11)	$51,500 20 months	Resource Engineering, Inc./*M. Epstein*
Exploratory Studies for Upgrading Coal and Heavy Oil (RP2655-14)	$98,300 10 months	Alberta Research Council/*L. Atherton*
Development: Novel Coal-Cleaning Process (RP2655-16)	$71,600 13 months	University of Akron/*C. Kulik*
Dow-Based IGCC Study for Low-Rank Coal (RP2699-9)	$310,100 10 months	Fluor Technology, Inc./*M. Gluckman*
Phased Repowering of Gallagher Station (RP2773-9)	$186,000 9 months	Fluor Technology, Inc./*C. Siebenthal*
Assessment: Extension of Life, Combustion Turbine Blades and Vanes (RP2775-2)	$299,900 29 months	IIT Research Institute/*J. Allen*
Assessment: Extension of Life, Combustion Turbine Blades and Vanes (RP2775-6)	$99,100 16 months	Southwest Research Institute/*J. Allen*
Development of a Continuous Monitor for H_2S, Geothermal Power Plants (RP2828-1)	$116,000 29 months	Pacific Gas and Electric Co./*V. Roberts*
Point-Contact Photovoltaic Module Testing (RP2948-1)	$64,200 6 months	Pacific Gas and Electric Co./*J. Bigger*
Coal Combustion Systems		
Validation: Heat Pipe Heat Exchanger Technology (RP1403-20)	$700,600 13 months	Babcock & Wilcox Co./*S. Divakaruni*
Nondestructive Tests for Temper Embrittlement (RP1957-7)	$120,600 23 months	Daedalus Associates, Inc./*S. Gehl*
Steam Turbine Rotor Life Assessment: Cyclic Life Evaluation of Rotors (RP2481-6)	$562,700 28 months	Failure Analysis Associates/*J. Byron*
Steam Turbine Rotor Life Assessment (RP2481-7)	$68,600 34 months	Materials Properties Council, Inc./*R. Dooley*
Site Support: Backdog Fluidized-Bed Power Generation (RP2628-6)	$64,000 1 year	Hamilton Mauer International/*S. Ehrlich*
Demonstration: Nucla Circulating Fluidized Bed (RP2683-1)	$10,000,000 3 years	Colorado-Ute Electric Assn., Inc./*T. Boyd*
CUEA Test Program Participation (RP2683-5)	$370,300 10 months	Colorado-Ute Electric Assn., Inc./*T. Boyd*
Control and Prevention of Fly Ash Erosion (RP2711-2)	$227,700 16 months	Combustion Engineering, Inc./*J. Byron*
Demonstration: EPRI Heat-Rate Improvement Guidelines (RP2818-2)	$240,000 2 years	Texas Utilities Electric Co./*G. Poe*
Feasibility Study: Atmospheric Fluidized-Bed Conversion (RP2843-1)	$100,000 13 months	Atlantic City Electric Co./*S. Tavoulareas*
Electrical Systems		
Transformer Life Characteristics (RP1289-1, -2)	$656,700 37 months	General Electric Co./*B. Bernstein*
PCDFs in Utility Equipment (RP2028-5–10)	$232,800 39 months	Battelle, Columbus Laboratories/*G. Addis*
Partial Combustion Products of Transformer Insulation Materials (RP2028-11, -12)	$129,900 10 months	Westinghouse Electric Corp./*G. Addis*
PCB Residue in Askarel Transformer Carcasses (RP2028-19)	$203,300 20 months	General Electric Co./*G. Addis*
Demonstration of PPP Cable Systems: 138 kV (RP7880-5)	$300,000 53 months	Consolidated Edison Co. of New York, Inc./*J. Shimshock*
Energy Management and Utilization		
Design Requirements and Market Assessment: Advanced Utility Loading Monitoring System (RP2568-10)	$143,500 8 months	New England Power Service Co./*L. Carmichael*
Methodology: Cool Storage Sizing (RP2732-12)	$93,900 13 months	Lawrence Berkeley Laboratory/*R. Wendland*
Energy Use of Ice Storage Systems With Low-Temperature Air (RP2732-16)	$97,000 28 months	Purdue Research Foundation/*R. Wendland*
Evaluation: Nonazeotropic Heat Pump Concepts (RP2792-9)	$456,900 3 years	National Bureau of Standards/*P. Joyner*
Soil and Rock Classification for Ground-Coupled Heat Pump Systems (RP2892-3)	$197,900 13 months	STS Consultants, Ltd./*P Joyner*
Design Criteria: Direct-Contact Ground Coils (RP2892-4)	$153,400 14 months	Martin Marietta Energy Systems, Inc./*P. Joyner*
End-Use Power Quality, Program Planning and Coordination (RP2935-10)	$350,000 26 months	Tennessee Center for R&D/*M. Samotyj*
Vortex Breakdown and Turbulent Mixing (RP8006-9)	$150,000 29 months	University of Houston/*J. Kim*
Environment		
Operational Evaluation of Regional Air Quality Models AUSPEX (RP2434-6)	$80,000 11 months	Pacific Gas and Electric Co./*P. Mueller*
Indoor/Outdoor Air Quality: Health Risk Assessment (RP2661-20)	$72,900 8 months	Kilkelly Environmental Associates, Inc./*C. Hakkarinen*
Response of Plants to Interacting Stresses (ROPIS) West (RP2799-3)	$871,400 19 months	University of California at Riverside/*R. Goldstein*
Literature Evaluation: Environmental Behavior of Select Organics (RP2879-2)	$243,300 15 months	Tetra Tech, Inc./*J. Guertin*
Fellowship Program: Compensatory Mechanisms of Fish Populations (RP2932-1)	$384,300 30 months	Sport Fishing Institute/*J. Mattice*
Nuclear Power		
Service Water System Sourcebook (RP2495-3)	$145,500 10 months	Heat Exchanger Systems, Inc./*N. Hirota*
Soil-Structure Interaction: Liquid Storage Tanks During Earthquakes (RP2907-2)	$74,400 15 months	Rice University/*H. Tang*
In Situ Cable Aging Assessment (RP2927-3)	$281,500 18 months	Franklin Research Center/*G. Sliter*
Erosion/Corrosion in Carbon Steel Feedwater Piping, Phase 1 (RP3000-9)	$83,600 8 months	Arizona State University/*V. Chexal*
Assessment of Steam Generator Sludge Lancing (S403-3)	$1,293,100 27 months	Foster-Miller, Inc./*C. Williams*

New Technical Reports

Requests for copies of reports should be directed to Research Reports Center, P.O. Box 50490, Palo Alto, California 94303; (415) 965-4081. There is no charge for reports requested by EPRI member utilities, U.S. universities, or government agencies. Others in the United States, Mexico, and Canada pay the listed price. Overseas price is double the listed price. Research Reports Center will send a catalog of EPRI reports on request. For information on how to order one-page summaries of reports, contact the EPRI Technical Information Division, P.O. Box 10412, Palo Alto, California 94303; (415) 855-2411.

ADVANCED POWER DIVISION

Proceedings: 9th Annual Geothermal and 2d IIE–EPRI Geothermal Conference and Workshop, Vols. 1 and 2
AP-4259-SR Special Report; Vol. 1, $62.50; Vol. 2, $62.50
EPRI Project Manager: V. Roberts

Heber Geothermal Binary Demonstration Plant: Design, Construction, and Early Startup
AP-5146 Topical Report (RP1900-5); $40
Contractor: Burns & McDonnell Engineering Co., Inc.
EPRI Project Managers: V. Roberts; J. Bigger

Reactive Power Management Device Assessment
AP-5210 Final Report (RP1590-8); $25
Contractor: University of Washington
EPRI Project Manager: F. Goodman

Simulator-Analyzer for Binary-Cycle Geothermal Power Plants: User's Guide
AP-5253-CCML Computer Code Manual (RP2195-7)
Contractor: Esscor
EPRI Project Manager: V. Roberts

Proceedings: 6th Annual EPRI Contractors' Conference on Coal Gasification
AP-5343-SR Proceedings; $55
EPRI Project Manager: N. Holt

NO_x Reduction for Small Gas Turbine Power Plants
AP-5347 Final Report (RP2564-1); $25
Contractor: Solar Turbines Inc.
EPRI Project Manager: L. Angello

Fuel Processor Development for Multimegawatt Fuel Cell Power Plants
AP-5349 Interim Report (RP1777-1); $32.50
Contractor: International Fuel Cells Corp.
EPRI Project Manager: D. Rastler

The Use of Nonasbestos Friction Materials in Hydrogenerators
AP-5382 Final Report (RP1745-23); $32.50
Contractor: Daedalus Associates, Inc.
EPRI Project Manager: C. Sullivan

Acoustic and Vibration Techniques for Cavitation Monitoring
AP-5385 Final Report (RP2602-3); $32.50
Contractor: Atlantic Applied Research Corp.
EPRI Project Manager: C. Sullivan

ChemCoal Process Development Program
AP-5390 Final Report (RP2655-5, -8); $32.50
Contractor: University of North Dakota
EPRI Project Manager: C. Kulik

Costs of Sulfur Emission Control Systems
AP-5391 Final Report (RP2773-2); $32.50
Contractor: Ebasco Services Inc.
EPRI Project Manager: B. Louks

Reliability Analysis of a Fault-Tolerant Gas Turbine Control System
AP-5425 Final Report (RP2101-7); $25
Contractor: ARINC Research Corp.
EPRI Project Manager: G. Quentin

Oxygen Plants for Coal Gasification: Experience at the Cool Water GCC Power Plant
AP-5432 Final Report (RP2221-14); $32.50
Contractor: BOC Cryoplants
EPRI Project Manager: R. Frischmuth

Liquefaction Coprocessing: A Study of Critical Variables
AP-5453 Final Report (RP2383-1); $32.50
Contractor: University of Wyoming
EPRI Project Manager: C. Kulik

COAL COMBUSTION SYSTEMS

Particulate Emission and Operating Characterization of an Electrostatically Enhanced Fabric Filter Pilot Plant
CS-5196 Final Report (RP725-12); $32.50
Contractor: Southern Research Institute
EPRI Project Managers: R. Carr; W. Piulle

Calcium Spray Dryer Waste Management: Design Guidelines
CS-5312 Final Report (RP2708-1); $800
Contractor: ICF Northwest
EPRI Project Manager: D. Golden

Proceedings: 8th International Ash Utilization Symposium, Vols. 1 and 2
CS-5362 Proceedings (RP2422); Vol. 1, $55; Vol. 2, $55
Contractor: American Coal Ash Association
EPRI Project Manager: D. Golden

Continuous Vibration Signature Analysis
CS-5378 Final Report (RP1864-2); $300
Contractor: Radian Corp.
EPRI Project Manager: J. Scheibel

Pulse-Jet Fabric Filters for Coal-Fired Utility and Industrial Boilers
CS-5386 Final Report (RP1129-8); $500
Contractor: Southern Research Institute
EPRI Project Manager: W. Piulle

Retrofit FGD Cost Estimating Guidelines: Computer User's Manual
CS-5408-CCM Computer Code Manual (RP1610-3); $32.50
Contractor: Stearns Catalytic Corp.
EPRI Project Managers: R. Moser; P. Radcliffe

Erosion Resistant Coatings for Steam Turbines
CS-5415 Final Report (RP1885-2); $800
Contractor: General Electric Co.
EPRI Project Manager: T. McCloskey

Organic Coatings in Simulated Flue Gas Desulfurization Environments
CS-5449 Final Report (RP1871-5); $200
Contractor: Lehigh University
EPRI Project Manager: B. Syrett

Evaluation of Flue Gas Desulfurization Materials in the Mixing Zone: R. D. Morrow Sr. Generating Station
CS-5476 Final Report (RP1871-2); $500
Contractor: Battelle, Columbus Laboratories
EPRI Project Manager: C. Dene

ELECTRICAL SYSTEMS

The Nuclear Electromagnetic Pulse and the Electric Power Grid: A Different Perspective
EL-4351-SR Special Report; $32.50
EPRI Project Manager: M. Rabinowitz

Dynamic Security Assessment for Power Systems: Research Plan
EL-4958 Final Report (RP2496-1); $47.50
Contractor: ECC, Inc.
EPRI Project Manager: C. Frank

Power Plant Electrical Reference Series, 1–15
EL-5036 Series (RP2334); Vols. 1–15, $15,000
Contractor: Stone & Webster Engineering Corp.
EPRI Project Manager: D. Sharma

Extending Applications of the Transient Energy Function Method
EL-5215 Final Report (RP2206-5); $32.50
Contractor: Iowa State University
EPRI Project Manager: J. Mitsche

Effect of Space Charge on Surface Insulation of High-Voltage Direct-Current Bushings
EL-5230 Final Report (RP2115-12); $25
Contractor: General Electric Co.
EPRI Project Manager: S. Wright

Integration of Utility Communication Systems
EL-5242 Final Report (RP2473-14); $5000
Contractor: Energy & Control Consultants, Inc.
EPRI Project Manager: N. Balu

Evaluation of Improvements in the Installation of Rural Underground Transmission Lines
EL-5255 Final Report (RP7898-6); $25.00
Contractor: Foster-Miller, Inc.
EPRI Project Manager: T. Rodenbaugh

Economic Study of a Rural Underground Transmission System: A Site-Specific Case Study
EL-5257 Final Report (RP7898-7); $25
Contractor: Chas. T. Main, Inc.
EPRI Project Manager: T. Rodenbaugh

Economics of PPP-Insulated Pipe-Type Cable
EL-5279 Final Report (RP7880-2); $40
Contractor: Underground Systems, Inc.
EPRI Project Managers: S. Kozak; J. Shimshock

Finite Element Simulation and Automated Defect Detection for Thyristors
EL-5302 Final Report (RP2115-13); $25
Contractor: University of Michigan
EPRI Project Manager: H. Mehta

Experimental Study of the Undrained Uplift Behavior of Drilled Shaft Foundations
EL-5323 Final Report (RP1493-2); $47.50
Contractor: Cornell University
EPRI Project Manager: V. Longo

Experimental Analysis of Drilled Shaft Foundations Subjected to Repeated Axial Loads Under Drained Conditions
EL-5325 Final Report (RP1493-4); $47.50
Contractor: Cornell University
EPRI Project Manager: V. Longo

Review of Load Tests on Deep Foundations Subjected to Repeated Loading
EL-5375 Final Report (RP1493-4); $62.50
Contractor: Cornell University
EPRI Project Manager: V. Longo

Bubble Formation in Transformers
EL-5384 Final Report (RP1289-4); $25
Contractor: General Electric Co.
EPRI Project Manager: G. Addis

Characterization of Failed Solid-Dielectric Cables: Phase 2
EL-5387 Final Report (RP1782-1); $32.50
Contractor: Battelle, Columbus Laboratories
EPRI Project Manager: B. Bernstein

Handbook for Insulation Coordination of High-Voltage Dc Converter Stations
EL-5414 Final Report (RP2323-1, -2); $1000
Contractors: Chas. T. Main, Inc.; General Electric Co.
EPRI Project Managers: S. Wright; V. Tahiliani

Optical Power Line Voltage and Current Measurement Systems, Vols. 1 and 2
EL-5431 Final Report (RP2748); Vol. 1, $32.50; Vol. 2, $25
Contractor: National Bureau of Standards
EPRI Project Manager: S. Wright

Analysis of Polychlorinated Dibenzofurans and Polychlorinated Dibenzo-*p*-Dioxins in Transformers and Capacitors, Vol. 1
EL/EA-5443 Final Report (RP2028-6, -7, -10); $32.50
Contractors: New York State Department of Health; Battelle, Columbus Laboratories; Research Triangle Institute
EPRI Project Managers: G. Addis; J. Guertin

ENVIRONMENT

Sampling Guidelines for Groundwater Quality
EA-4952 Final Report (RP2485-1); $25
Contractor: Tetra Tech, Inc.
EPRI Project Manager: I. Murarka

Effect of Power Plant NO_x Emissions on Ozone Levels
EA-5333 Final Report (RP1375); $47.50
Contractor: Systems Applications Inc.
EPRI Project Manager: R. Wyzga

Compensatory Mechanisms in Fish Populations: An EPRI Research Plan
EA-5404 Final Report (RP1633-6); $25
Contractors: Science Applications International Corp.; R. G. Otto & Associates
EPRI Project Manager: J. Mattice

Operational Procedures to Evaluate Decisions With Multiple Objectives
EA-5433 Final Report (RP1433-2); $32.50
Contractor: University of Southern California
EPRI Project Manager: T. Wilson

Analysis of Polychlorinated Dibenzofurans and Polychlorinated Dibenzo-*p*-Dioxins in Transformers and Capacitors, Vol. 1
EL/EA-5443 Final Report (RP2028-7, -6, -10); $32.50
Contractors: New York State Department of Health; Battelle, Columbus Laboratories; Research Triangle Institute
EPRI Project Managers: G. Addis; J. Guertin

Evaluation of Regional-Scale Air Quality Models
EA-5473 Final Report (RP1630-40); $32.50
Contractor: Battelle, Pacific Northwest Laboratories
EPRI Project Managers: G. Hilst; L. Levin; A. Hansen

ENERGY MANAGEMENT AND UTILIZATION

Small-Hydropower Development: The Process, Pitfalls, and Experience—Vol. 3: Summary and Analysis of Technology Development Projects
EM-4036 Final Report (RP1745-15); $55
Contractor: Morrison-Knudsen Engineers, Inc.
EPRI Project Manager: C. Sullivan

Electroslag Processing: State-of-the-Art Assessment
EM-4992 Final Report (RP2570-1); $25
Contractor: Center for Metals Production
EPRI Project Manager: R. Jeffress

Residential Load Control and Metering Equipment: Costs and Capabilities
EM-5392 Final Report (RP1940-13); $25
Contractor: Electrotek Concepts, Inc.
EPRI Project Manager: L. Carmichael

Residential Heating, Ventilating, and Air Conditioning Research Workshop
EM-5398 Final Report (RP2792-4); $25
Contractor: Analysis and Control of Energy Systems, Inc.
EPRI Project Manager: P. Joyner

Electrotechnologies for Waste and Water Treatment
EM-5418 Final Report (RP2416-25); $47.50
Contractor: Science Applications International Corp.
EPRI Project Managers: A. Karp; L. Harry

A Continuous Electric Kiln for Rapid Sintering
EM-5436 Final Report (RP2730-3); $25
Contractor: Harrop Industries, Inc.
EPRI Project Manager: A. Karp

Technoeconomic Assessment of Electric Steelmaking Through the Year 2000
EM-5445 Final Report (RP2787-2); $40
Contractor: Center for Metals Production
EPRI Project Manager: R. Jeffress

Field Evaluation of Cold Air Distribution Systems
EM-5447 Final Report (RP2732-3); $150
Contractor: Dorgan, McMahon and Associates, Inc.
EPRI Project Manager: R. Wendland

Proceedings: 3d National Conference on Utility Demand-Side Management Programs
EM-5452 Proceedings (RP2050-11); $85
Contractor: Synergic Resources Corp.
EPRI Project Manager: S. Braithwait

Field Test of Electric Vehicle Battery Chargers
EM-5456 Final Report (RP2037-4); $32.50
Contractor: Detroit Edison Co.
EPRI Project Manager: L. O'Connell

DSM Technology Alternatives
EM-5457 Interim Report (RP2548-1); $1000
Contractors: Battelle, Columbus Division; Enviro-Management & Research, Inc.
EPRI Project Managers: W. Smith; O. Zimmerman

Personal Computer Software for Lighting Design and Analysis
EM-5463 Final Report (RP2418-6); $25
Contractor: Analysis and Control of Energy Systems, Inc.
EPRI Project Manager: K. Johnson

Heat Recovery Heat Pumps in Commercial Buildings
EM-5464 Final Report (RP2480-4); $150
Contractor: Dames & Moore
EPRI Project Manager: M. Blatt

NUCLEAR POWER

ARMP-02 Documentation Part II, Chapter 2—Description of the CELL-2 Fast and Thermal Cross-Section Libraries
NP-4574-CCM Part II, Chapter 2, Computer Code Manual (RP118-1); $25
Contractors: Los Alamos National Laboratory; Louisiana State University; Nuclear Associates International Corp.
EPRI Project Manager: O. Ozer

ARMP-02 Documentation Part II, Chapter 8—SIMULATE-E (Mod. 3) Computer Code Manual
NP-4574-CCM Part II, Chapter 8, Computer Code Manual (RP976-3); $55
Contractor: Science Applications International Corp.
EPRI Project Manager: O. Ozer

Advanced Core-Monitoring Framework Computer Code Manual, Vols. 1–3
NP-5227M Computer Code Manual; $32.50
NP-5227SP, Computer Code Manual; Vols. 1–3, $100,000
Contractor: Systems Control, Inc.
EPRI Project Manager: D. Cain

Residual and Applied Stress Analysis of an Alloy 600 Row 1 U-Bend
NP-5282 Final Report (RPS303-3); $32.50
Contractor: The Pennsylvania State University
EPRI Project Manager: A. McIlree

Guidelines for Permanent BWR Hydrogen Water Chemistry Installations—1987 Revision
NP-5283-SR-A Special Report; $32.50
EPRI Project Manager: R. Jones

PWR Pilot Plant Life Extension Study at Surry Unit 1: Phase 1
NP-5289P Final Report (RP2643-1); $50,000
Contractors: Virginia Power; Grove Engineering Inc.; Westinghouse Electric Corp.; Stone & Webster Engineering Corp.; Temple, Barker & Sloane, Inc.
EPRI Project Manager: M. Lapides

Utility Machinery Vibration Monitoring Guide
NP-5311 Final Report (RP824-3); $55
Contractor: Radian Corp.
EPRI Project Managers: G. Shugars; F. Gelhaus

PWR Pressurizer Transient Response
NP-5357 Final Report (RP443-3); $32.50
Contractor: Dartmouth College
EPRI Project Manager: J. Sursock

Designs and Costs of Low-Level Waste Disposal Facilities
NP-5365M Interim Report (RP2691-1); $25
NP-5365S Interim Report; $20,000
Contractor: Rogers and Associates Engineering Corp.
EPRI Project Manager: R. Shaw

Compact Analyzer for BWR Applications
NP-5366 Final Report (RP2395-5); $32.50
Contractor: S. Levy, Inc.
EPRI Project Manager: R. Colley

Filtration Improvement Study at Three Mile Island, Unit 2
NP-5367 Final Report (RP2414-15); $32.50
Contractor: Vance & Associates
EPRI Project Manager: P. Robinson

Intergranular Attack of Alloy 600 Tubing: Simulation Tests
NP-5377 Interim Report (RPS302-4); $32.50
Contractors: Commissariat à l'Energie Atomique; Framatome
EPRI Project Managers: D. Cubicciotti; J. Peter; N. Paine

Visual Weld Acceptance Criteria, Vols. 1–3
NP-5380 Final Report (RPQ101); Vols. 1–3, $75
Contractor: Reedy Associates, Inc.
EPRI Project Manager: W. Bilanin

Nuplex Project Briefs
NP-5388M Final Report (RP2643-15); $25
NP-5388SP Final Report; $3500
EPRI Project Manager: M. Lapides

User's Guide for Signal Validation Software
NP-5389 Final Report (RP2292-2); $32.50
Contractor: Performance Associates, Inc.
EPRI Project Manager: J. Naser

Intergranular Corrosion Mechanisms of Alloy 600
NP-5396 Final Report (RP2163-5); $32.50
Contractor: Commissariat à l'Energie Atomique
EPRI Project Managers: J. Paine; D. Cubicciotti

High-Purity Steels for Utility Components
NP-5399 Final Report (RP2060-1, -2); $47.50
Contractors: Japan Steel Works; Bethlehem Steel Corp.
EPRI Project Manager: R. Jaffee

Modeling of Molten Corium–Concrete Interaction
NP-5403 Interim Report (RP1933-3); $40
Contractor: Massachusetts Institute of Technology
EPRI Project Manager: R. Sehgal

Nonintrusive Measurement of Liquid Film Velocity and Flow Rate
NP-5407 Final Report (RP494-5); $25
Contractor: State University of New York at Buffalo
EPRI Project Manager: M. Merilo

Automatic Sizing of Intergranular Stress Corrosion Cracking With IntraSpect/98
NP-5409 Topical Report (RP1570-2); $25
Contractor: J. A. Jones Applied Research Co.
EPRI Project Manager: M. Behravesh

Nondestructive Evaluation of Ferritic Piping for Erosion-Corrosion
NP-5410 Topical Report (RP1570-2); $40
Contractor: J. A. Jones Applied Research Co.
EPRI Project Manager: M. Behravesh

Turbine Protection System Evaluation
NP-5416 Final Report (RP2641-1); $32.50
Contractor: Foster-Miller, Inc.
EPRI Project Manager: B. Brooks

EPRI Nondestructive Evaluation Center: 1986 Annual Report
NP-5419 Interim Report (RP1570-2); $32.50
Contractor: J. A. Jones Applied Research Co.
EPRI Project Manager: G. Dau

Dimensional Analysis of Natural Circulation Experiments
NP-5428 Final Report (RP1227-5); $25
Contractor: Technion Institute of Technology
EPRI Project Manager: J. Sursock

Nickel Chromium Iron Alloys for Nuclear Reactor Vessel Components
NP-5429M Final Report (RP2058-4); $25.00
NP-5429SP, Vol. 1, $4800; Vol. 2, $9500
Contractor: Babcock & Wilcox Co.
EPRI Project Manager: J. Nelson

Application of Reliability-Centered Maintenance to San Onofre Units 2 and 3 Auxiliary Feedwater Systems
NP-5430 Final Report (RP2508-8); $32.50
Contractor: Erin Engineering and Research Inc.
EPRI Project Manager: J. Gaertner

Fracture Toughness Characterization of Thermally Embrittled Cast Duplex Stainless Steel
NP-5439 Final Report (RP1543-12); $25
Contractor: Fracture Control Corp.
EPRI Project Manager: D. Norris

BWR Radiation Control: In-Plant Demonstration at Vermont Yankee
NP-5455 Final Report (RP1934-1); $32.50
Contractor: NWT Corp.
EPRI Project Manager: C. Wood

Component Life Estimation: LWR Structural Materials Degradation Mechanisms
NP-5461 Interim Report (RP2643-5); $5000
Contractor: Structural Integrity Associates, Inc.
EPRI Project Manager: M. Lapides

Fracture Mechanics Evaluation of Feedwater Line Failure at Surry-2
NP-5462 Final Report (RP1757-65); $25
Contractor: Novetech Corp.
EPRI Project Manager: D. Norris

Effects of Ultrasonic Equipment Variations on Crack Length Measurements
NP-5485 Final Report (RP1570-2); $25
Contractor: J. A. Jones Applied Research Co.
EPRI Project Manager: G. Dau

PLANNING AND EVALUATION

TAG Technical Assessment Guide, Vols. 2 and 4
P-4463-SR Special Report; Vol. 2, Pt. 1, $300; Vol. 4, $40
EPRI Project Manager: T. Yau

Proceedings: 1986 Fuel Supply Seminar
P-5417 Proceedings (RP2369-10); $40
Contractor: Atlantis, Inc.
EPRI Project Manager: J. Platt

New Computer Software

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For more information about EPSC and licensing arrangements, EPRI member utilities, government agencies, universities, and other tax-exempt organizations should contact the Electric Power Software Center, Power Computing Co., 1930 Hi Line Drive, Dallas, Texas 75207; (214) 655-8883. Industrial organizations, including nonmember utilities, should contact EPRI's Manager of Licensing, P.O. Box 10412, Palo Alto, California 94303; (415) 855-2866.

DIRECT: Transient Energy Function Program
Version 1.1 (IBM, PRIME, VAX); E1-4980
Contractor: Ontario Hydro
EPRI Project Manager: Giora Ben-Yaacov

MIDAS: Multiobjective Integrated Decision Analysis System
Version 1.0 (IBM-PC)
Contractors: Temple, Barker & Sloane; M. S. Gerber & Associates
EPRI Project Manager: Hung-Po Chao

OVER/UNDER: Cost and Benefits of Over Versus Under Capacity
Version 3.0 (IBM, VAX); P-5233
Contractor: Decision Focus
EPRI Project Manager: Hung-Po Chao

POSSM: Chemical Spill Exposure Assessment Methodology
Version 2.0 (IBM-PC)
Contractor: CH2M
EPRI Project Manager: Abe Silvers

RETROFGD: Retrofit Flue Gas Desulfurization Program
Version 1.2 (IBM-PC); CS-5408
Contractor: Stearns Catalytic
EPRI Project Manager: Paul Radcliffe

SPEEDM: Solid-Particle Erosion Economic Decision Methodology
Version 1.0 (IBM-PC); CS-5239
Contractor: General Electric Co.
EPRI Project Manager: T. H. McCloskey

CALENDAR

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

APRIL

11–12
Conference: Hydro Power Plant Relicensing
Washington, D.C.
Contact: Jim Birk (415) 855-2562

13–14
Symposium: Radiant Barriers
Chattanooga, Tennessee
Contact: John Kesselring (415) 855-2902

MAY

2–4
Conference: Hydro O&M
Washington, D.C.
Contact: Laura Goldie (415) 855-2560

3–4
Workshop: Residential/Unitary Cool Storage R&D
Dallas, Texas
Contact: Don Geistert (415) 855-2993

3–5
1988 Seminar: FBC Technologies for Utility Applications
Palo Alto, California
Contact: Stratos Tavoulareas (415) 855-2424

5–6
7th Reactor Physics Software Users Group Meeting
Allentown, Pennsylvania
Contact: Walter Eich (415) 855-2090

10–12
1988 Conference: Heat Rate Improvement
Richmond, Virginia
Contact: Robert Leyse (415) 855-2995

23–25
Conference: Hydro O&M
San Francisco, California
Contact: Laura Goldie (415) 855-2560

23–26
International Conference: Validation of Flow and Transport Models for the Unsaturated Zone
Ruidoso, New Mexico
Contact: Ishwar Murarka (415) 855-2150

JUNE

6–10
Symposium: Feedwater Heater Technology
Winston-Salem, North Carolina
Contact: John Tsou (415) 855-2220

13–15
Life Extension and Assessment of Fossil Fuel Plants
The Hague, Holland
Contact: Barry Dooley (415) 855-2658

AUGUST

30–September 1
Second Conference on Cycle Chemistry in Fossil Fuel Plants
Seattle, Washington
Contact: Barry Dooley (415) 855-2458

SEPTEMBER

21–23
2d International Symposium: Probabilistic Methods Applied to Electric Utilities
Oakland, California
Contact: Dick Kennon (415) 855-2311

OCTOBER

17–20
8th Annual Coal Gasification Conference
Palo Alto, California
Contact: Neville Holt (415) 855-2503

18–19
Workshop: Upgrading Low-Rank Coals
Denver, Colorado
Contact: Clark Harrison (412) 479-3505

25–28
Symposium: FGD and Dry SO_2 Control
Saint Louis, Missouri
Contact: Paul Radcliffe (415) 855-2720

NOVEMBER

29–December 1
2d EPRI Conference: Fossil Fuel Plant Inspection
San Antonio, Texas
Contact: Stephen Gehl (415) 855-2770

Authors and Articles


Lannus


Barker


Ehrlich


Minor


Tang


Wall

The Advanced Heat Pump: All the Comforts of Home . . . and Then Some (page 4) was written by Taylor Moore, *Journal* senior feature writer, with technical guidance from **Arvo Lannus** of EPRI's Energy Management and Utilization Division. Lannus manages a research program dealing with residential and commercial energy applications. An Institute staff member since May 1980, he was formerly director of advanced technology for Gordian Associates, responsible for research on heat pumps and energy use in buildings. Earlier, Lannus was on the chemical engineering faculty of Cooper Union School of Engineering. He has a BS in chemistry and a PhD in chemical engineering, both from Drexel University. ■

Deregulation: Facing the Big Question (page 14) is a summary of divergent opinions and predictions set forth at EPRI's 1987 Advisory Council Seminar; it was written by **Brent Barker,** the *Journal*'s editor in chief.

Barker, a business writer since 1973, was a communications consultant before he took responsibility for the *Journal* in 1977. He was formerly an industrial economist at SRI International and a commercial research analyst at USX Corp. Barker graduated from Johns Hopkins University in engineering science and earned an MBA at the University of Pittsburgh. ■

Employee Loans With Technology Payback (page 24) was written by Ralph Whitaker, *Journal* feature editor, in cooperation with two members of EPRI's technical and administrative management.

Shelton Ehrlich, manager of the Fluidized Combustion Program, has specialized in fluidized-bed R&D for more than 20 years. Before coming to EPRI in 1975, he was with Pope, Evans & Robbins for eight years as director of combustion research. Still earlier, he worked for four years in nuclear engineering. Ehrlich has a BS in mechanical engineering from the University of Missouri and an MS in nuclear engineering from the University of California at Berkeley.

Bill Minor, EPRI's manager of staff planning and recruitment, has been in personnel work for five years, following four years in EPRI's financial and administrative management. Before coming to the Institute, he was an engineering and proposal administrator with Dalmo Victor, a Singer Co. division. Minor has a BS in business administration from California State University (Hayward) and an MBA from the College of Notre Dame (Belmont, California). ■

Concrete Containments Handle the Pressure (page 32) was written by Jon Cohen, science writer, who was aided by two staff members of EPRI's Nuclear Power Division.

Hui-tsung Tang, a seismic research program manager, is particularly concerned with matters of structural integrity. He has been at EPRI since 1978, following six years with the nuclear energy division of General Electric, where he became a senior engineer and technical leader for nuclear containment technology. Tang completed his undergraduate engineering study in Taiwan; he also has an MS and a PhD in applied mechanics from the University of California at San Diego.

Ian Wall, senior program manager for risk assessment, has worked in nuclear safety technology since he came to EPRI in 1979. Before that he headed the risk analysis branch of the NRC Office of Regulatory Research. Still earlier, Wall worked for ten years with the nuclear energy division of General Electric. First educated in England, Wall also holds an ScD in nuclear engineering from the Massachusetts Institute of Technology. ■

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