Tools for Hydro Relicensing

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Cover: Relicensing is driving the development of an integrated set of tools for balancing the power and nonpower values of U.S. hydroelectric resources.

Hydro Relicensing: Taking the Proactive Approach

Regardless of how deregulation unfolds for the utility industry as a whole, competition is already here for hydroelectric generation. The Electric Consumers Protection Act (ECPA) of 1986 provides for open bidding on existing hydro projects, creating an opportunity for competitors to take over a number of projects that are coming up for relicensing. Although the 4000 MW of capacity at stake in the 1990s is not a large resource, hydro is often the cheapest and most flexible option in many utility portfolios. Replacement of this capacity would cost billions.

With or without competition for hydro projects, the incumbent has two options. The first—the responsive strategy—involves continuation of the long-standing, successful use of the resource, with facility and operating changes designed to provide environmental and recreational enhancement. Such changes would respond to the recommendations of individual resource interest groups, such as fish and wildlife agencies. With the second option—the proactive strategy—utilities would modernize or upgrade hydro projects, using their own judgment to appropriately accommodate environmental and recreational needs.

Superficially, both of these appear to be effective strategies for beginning the next half-century of hydro plant deployment. However, simply responding to agency recommendations may not result in a relicensing plan that appropriately balances the various uses of water and that is, in the words of ECPA, "best adapted to serve the public interest." Agency recommendations seldom look beyond a particular area of interest, and unless the plan is balanced and best adapted, the incumbent licensee could lose the project. Further, since agency recommendations are not guided by cost concerns, their implementation could lead to very expensive solutions.

A proactive strategy, on the other hand, has a number of beneficial effects. Plant upgrading and modernization can improve efficiency, lower costs, and enhance power output. And proposing their own recreational and environmental improvements not only allows utilities to demonstrate their interest in the public welfare but also ensures that these benefits will be economical and best balanced for the whole of society, not just for the most vocal groups.

Technology plays a key role in the proactive strategy. For example, effective plant upgrading will depend on improved materials and designs, modern diagnostic instrumentation, and greater use of automation; similarly, innovative, cost-effective options for oxygenating plant discharges and detouring fish around turbines will be important for addressing environmental issues. EPRI has developed and/or evaluated an array of such technological products. Putting them into use with a proactive management strategy will mitigate the threat of competition, improve project economics, enhance a valuable resource, promote a favorable public perception of the utility, and even open the door to new opportunities. One such opportunity is to truly get out in front of the situation—to apply the products and strategy without regard to the license expiration date.

James R. Birk

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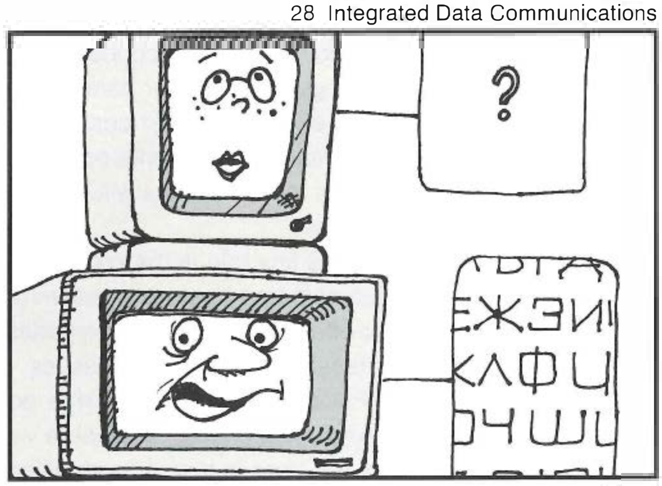

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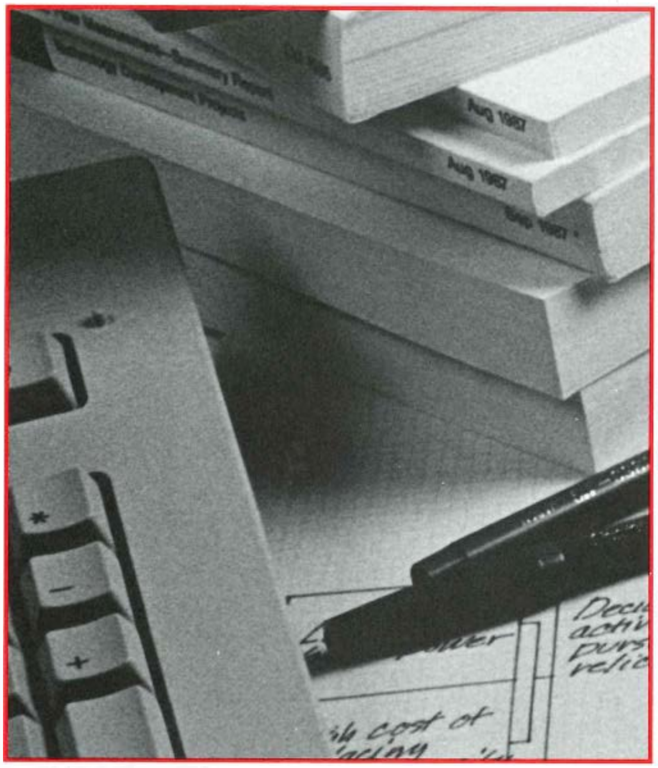

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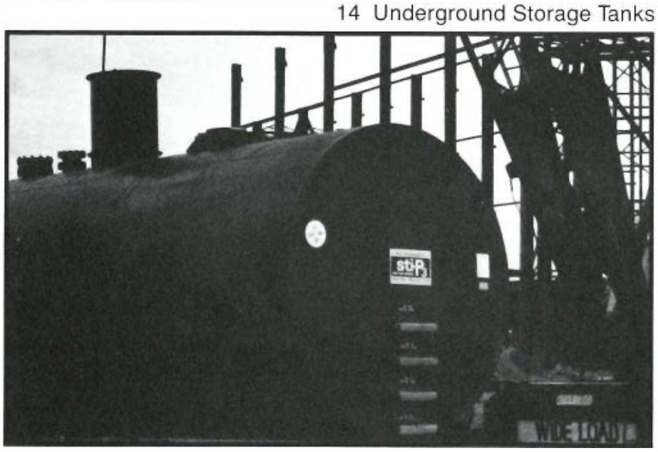
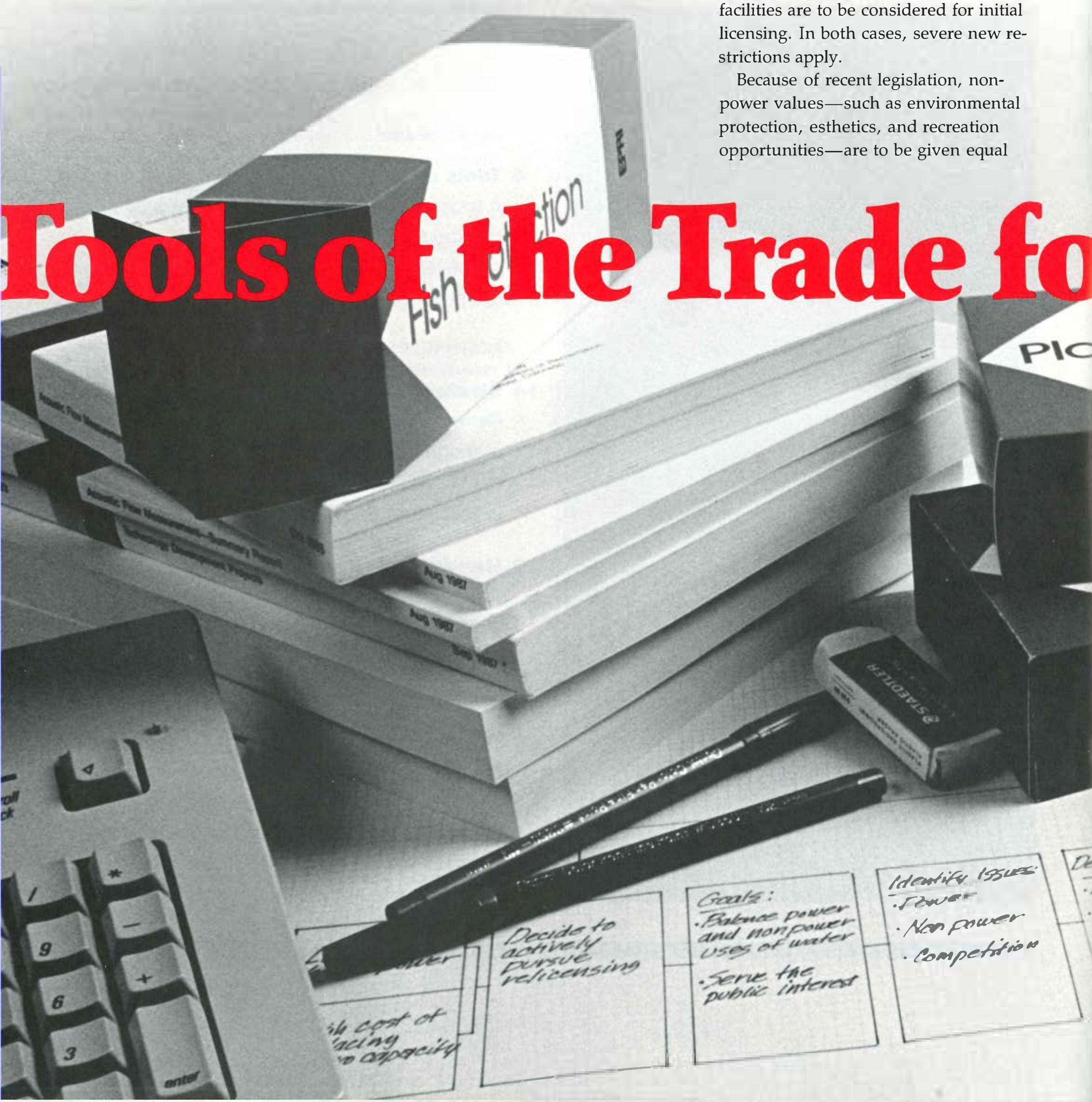


Hundreds of hydro projects will come up for relicensing over the next decade, with new rules and new priorities governing the process. EPRI is developing a toolbox full of technology and techniques to help utilities put together successful licensing strategies.

After years of being taken for granted as one of the most reliable, cost-effective, and environmentally acceptable ways to generate electricity, hydropower is currently being subjected to unprecedented scrutiny. Between now and the turn of the century, roughly 300 existing hydroelectric projects are due for relicensing, and dozens of new facilities are to be considered for initial licensing. In both cases, severe new restrictions apply.

Because of recent legislation, nonpower values—such as environmental protection, esthetics, and recreation opportunities—are to be given equal

Tools of the Trade fo



consideration with power generation in determining whether and how a hydroelectric facility can be operated. State and federal resource agencies, including fisheries and wildlife agencies and water quality boards, will play a more direct role in determining the acceptability of a project. And license applications from competitors will be considered with those of current project operators, although significant differences in the utilization of a resource for the public good would have to be demonstrated before a facility would be taken away from a current licensee.

At the same time, technological advances and a changing business climate have opened new opportunities for hydropower. Plant modernization can enhance both the capacity and reliability of existing hydroelectric projects, while increased use of pumped hydro can provide utilities an important buffer between customer demand and available generating capacity.

"Hydropower is on the threshold of a new era," says James Birk, department director for advanced conversion and storage in the Advanced Power Systems Division. "Relicensing can serve as a useful catalyst for utilities to improve their hydroelectric projects and protect a huge, valuable investment. EPRI has developed a tool box of methodologies that utilities can use at each step of the way—more approaches to environmental protection, new technologies that can improve plant performance, and analytic methods for evaluating options to modernize plants and improve hydro projects."

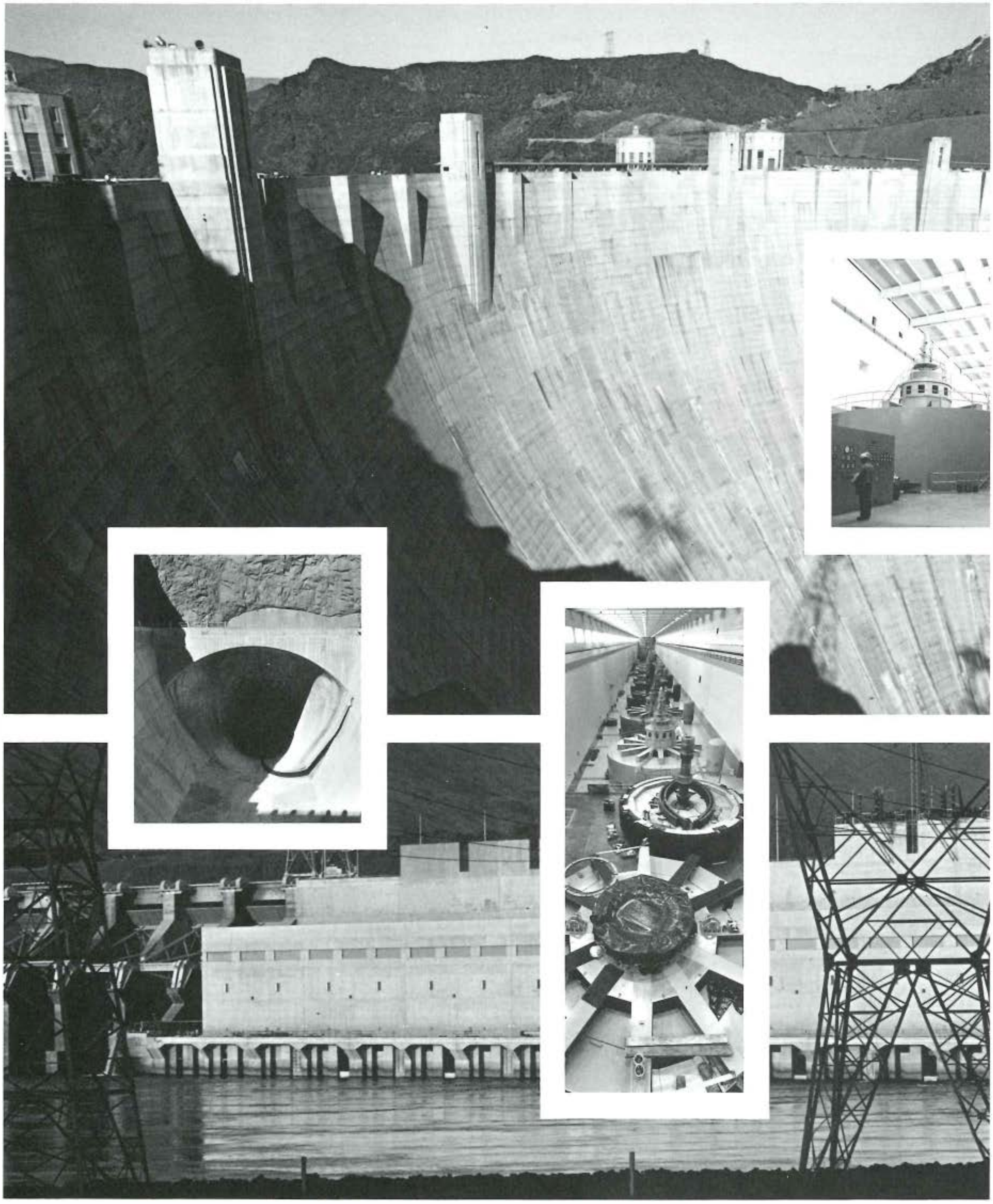
The policy pendulum

A decade ago, in the wake of the oil embargo and rising fuel prices, the Public Utility Regulatory Policies Act (PURPA) encouraged development of hydropower as a domestic alternative to imported oil. State and federal tax incentives also helped make previously uneconomical small-hydro sites viable

Hydro Relicensing

Water as an Economic Engine

Since Niagara Falls first generated electricity nearly 100 years ago, hydro plants have best symbolized the clean capture of energy from nature. But eventual replacement of long-running turbines and generators, as well as their auxiliary controls, gates, valves, and switches, provides an opportunity for new technology to revitalize an old resource, even upgrading its energy productivity.



for power production. Some older, decommissioned hydroelectric facilities were brought back into service. By 1983 the U.S. Army Corps of Engineers concluded that 46 gigawatts of additional hydro capacity could be brought on-line by the end of the century.

Such projections now seem quite overoptimistic in light of low demand growth, less costly fossil fuel, and recent legislation and regulatory changes. The Tax Reform Act removed many of the earlier tax incentives developers had received for building alternative energy facilities, such as hydro. The Electric Consumers Protection Act (ECPA) of 1986 brought new complexity to the licensing and relicensing of hydroelectric facilities. Then in 1987 the Federal Energy Regulatory Commission (FERC)—the agency in charge of hydro licensing—interpreted the provisions of ECPA by issuing strict new rules related to environmental protection, participation of resource agencies, and the information that existing facility owners must make available to potential competitors.

This dramatic swing in national policy was brought about by several factors. Within the electric power industry, the need for new capacity diminished as load growth fell below expectations, so utilities were less eager to build new generating facilities of any kind. As fuel prices declined, the economic feasibility of many small-hydro sites became doubtful. New demands arose that public resources, such as rivers used to produce hydropower, be exploited in a more balanced fashion, with greater emphasis placed on recreation and environmental protection. In addition, awareness grew that hydroelectric facilities might not be as environmentally benign as previously thought.

Since the early 1900s, for example, declines in the salmon population of the Columbia River and in the mussel population of the Tennessee River have raised questions about the effects of numerous dams and power generating facilities on those river systems. Extensive studies of commercially and recreationally important fisheries have not been able to determine how much of the decline resulted from hydropower development and how much from other causes, such as overharvesting. The studies did, however, reveal a pressing need to better understand the ecologic effects of hydroelectric plants. With the emergence of a new regulatory climate, the responsibility for determining these effects and mitigating them has increasingly fallen on electric utilities that own hydropower facilities.

Impacts reexamined

Hydro development can affect the environment in numerous ways. Dams without fish ladders prevent the upstream passage of anadromous fish (such as salmon), which must migrate upstream to spawn. Downstream passage of fish through turbines results in a still uncertain level of death and injury. Tentative estimates place turbine mortality roughly in the range of 10–50% for hydroelectric plants, but such numbers remain very controversial. Reductions in the volume of water below a dam during periods of low electricity generation—the so-called instream flow issue—may affect various aquatic species in ways not yet fully understood.

In addition, water downstream from a dam may have very different temperature, turbidity, nutrients, dissolved gases, and levels of toxicants than do naturally flowing streams in the same area. Such differences do not always occur, and often they are within the normal tolerance range of plants and animals. Some changes may even prove advantageous. For example, some valuable species of cold-water fish can now be harvested from the tailwaters of dams in the southeastern United States because of the cooling effect of water passed from the depths of a reservoir. On the other hand, such tailwaters may have levels of dissolved oxygen that are too low to sustain certain types of fish downstream, or they may have such high levels of dissolved nitrogen from aeration that fish may suffer from a disorder similar to the bends.

Even the act of constructing hydropower facilities—some of which rank among the civil engineering wonders of the world—can have a lasting effect on regional ecology. Some direct physical damage is obvious, including the bulldozing of hillsides, building of roads, and other so-called big foot effects. Less obvious, indirect effects, such as increased erosion and the disruption of habitats, and cumulative or synergistic environmental impacts among multiple dams along a single river system are difficult to assess.

"Two major research efforts are needed to help utilities minimize ecologic damage from hydro facilities and meet the environmental requirements of relicensing," says Jack Mattice, project manager in the Environment Division. "First, we must develop better assessment tools that can help us predict the occurrence and severity of ecologic effects much better than we do now. Second, we have to find more-sophisticated technologies to mitigate those effects, when necessary."

Environmental initiatives

The most immediately pressing environmental issue, according to an EPRI study published in 1986, is how to protect migrant fish during their movement downstream. (Use of fish ladders and other devices to assist the upstream passage of anadromous fish has already been implemented widely.) During the study, conducted by Stone & Webster Engineering, dozens of fish protection systems were examined, ranging from electrical screens that drive fish away from turbine intakes to moving buckets that physically carry fish to safety. The study's conclusion: "It is clear that no single existing sytem is biologically effective, operationally reliable, economically feasible, and acceptable to regulatory agencies."

Since this study was completed, EPRI has sponsored continuing research to improve fish protection systems. Some of the more promising approaches combine traditional fish barriers with behavioral devices, such as mercury lamps that attract fish to bypass routes. In addition, EPRI is sponsoring tests of acoustic monitors that continuously measure how many fish actually pass through a turbine.

"Although no one device or method is going to solve everyone's problems, attracting fish with mercury lamps, in conjunction with other methods, can be used cost-effectively at many sites," says Charles Sullivan, hydro program manager in the Advanced Power Systems Division. "We're continuing several field tests on fish protection systems to optimize their effectiveness. In the meantime, EPRI's guides and assessments can help utilities to critically examine the alternatives already available and choose which ones might be best for them."

Another environmental issue currently receiving increased attention involves the question of how much instream flow is required below a dam to maintain the biologic and esthetic resources of a waterway. Here the problem is not so much one of mitigation—stream flow can usually be controlled within wide margins, and other options may be available to enhance stream habitats. Rather, the problem is the lack of a commonly agreed-upon method for determining just how much flow is enough under particular circumstances.

Not that researchers haven't tried. More than 75 methods for determining the effect of instream flow on biologic variables or for recommending appropriate flow levels were reviewed for EPRI by EA Engineering, Science, and Technology. Results of this review, published in 1986, showed that none of the methods had been sufficiently verified in the field to assess the accuracy or geographic limits of their predictive abilities.

Continuing EPRI work in this area includes gathering more data that can be used to validate instream flow models, together with designing new models that can predict measurable biologic effects more accurately. The importance of instream flow appears to differ drastically from one site to another. Spawning beds near the tailwaters of a hydroelectric facility, for example, may be quite susceptible to variations in instream flow. In one such case, mitigation has taken the form of providing additional spawning grounds by using weirs rather than releasing more water when power is not being generated.

A third major area of environmental research focuses on predicting and controlling the amount of dissolved oxygen in the tailwaters of a dam, which must meet federal and state standards. During the summer, water at the surface of a deep reservoir may be 10–20°C warmer than water near the bottom. This temperature gradient results in stratification, caused by density differences between warm and cold water, and thus prevents mixing of water at various depths. Oxygen depleted from deep waters through the action of bacteria is not replaced by aeration from the surface or by photosynthesis. Since the turbine intake level for many hydroelectric facilities is located far below the reservoir surface, for several weeks each year tailwaters may have only a fraction of the dissolved oxygen needed to support some species of fish.

Although the cause of this problem is well understood, it may be hard to predict either the oxygen levels at a particular site or the effects of varying concentrations on different fish species. More data are needed, both on the site-specific factors that affect dissolved oxygen and on the response of fish to changing oxygen levels. EPRI's strategy in this area is to review the results of studies on how small changes in dissolved oxygen affect fish, to survey utility experience with on-line instrumentation that measures dissolved oxygen, and to document various oxygen enhancement options.

Several options for increasing dissolved oxygen in tailwaters are currently being tried experimentally at utility sites. A pipe leading from the atmosphere to the turbine, for example, can be used to dissolve more air in the water stream as it passes through a hydro plant. Propellers with 15-foot blades can be floated on a reservoir near a dam to force oxygenated surface water down toward the turbine intake. Even tanks of liquid oxygen have been used to supply a diffuser that adds the gas directly to water in a reservoir, much like the bubbler in a home aquarium. Since no single solution appears ideal for all circumstances, EPRI's aim is to condense available information and identify cost-effective alternatives for dealing with this water quality issue.

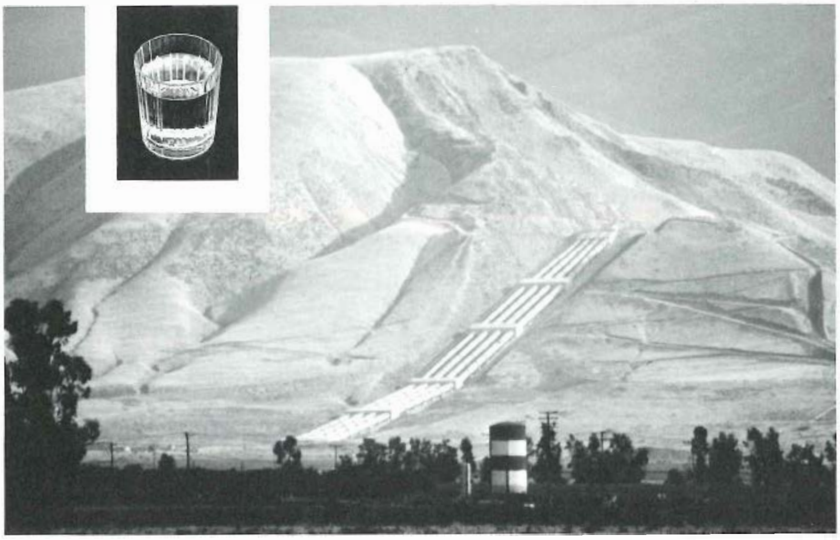
Dam safety

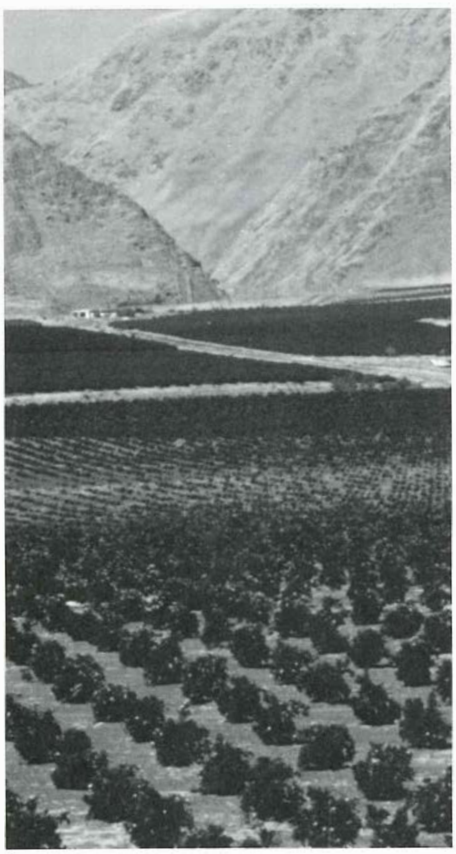
Although utility dams have an outstanding safety record, a series of dam failures worldwide has caused a tightening of federal safety regulations. Owners of licensed dams are now required to conduct annual inspections and have independent consultants perform design reviews every five years, using current criteria. In some instances, the effect of more-stringent design criteria is exacerbated by lack of dam design drawings and by the fact that modern soil and rock mechanics theory was developed after many of today's existing dams were constructed.

Some of the issues in question include the accuracy of methods used to

Water as a Life Support System

The needs of people and their agriculture are the highest overall priorities for water use, but differences in regional economies, populations, and climates, as well as site-specific streamflows, reservoir capacities, and settings, make every hydroelectric project an individual complex of multiple uses and values.





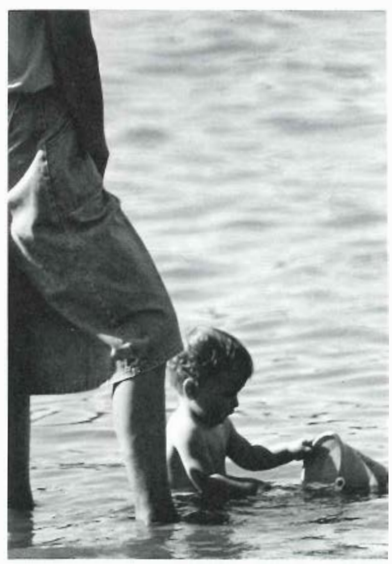
measure uplift water pressure under dams, the effectiveness of drainage systems, the condition of dam concrete and rock foundations, the ability of a dam to resist sliding, and doubts about the expected performance of a dam under flood conditions. "EPRI is conducting a dam safety research program to address these issues," says Project Manager Douglas Morris. "This program can help utilities collect site-specific data, implement safety analyses with modern analytic tools, and evaluate improvement alternatives. With such an approach, they may be able to avoid having to anchor dams or make other unnecessary modifications, at a cost of several million dollars per site."

For concrete gravity dams (i.e., those held in place mostly by the weight of the dam against underlying bedrock) federal criteria must be used in determining the factors of safety that prevent a dam from overturning or sliding. Overturning can be caused by the weight of the water in the reservoir pushing on the dam or by similar forces caused by ice and silt buildup. Contributing to this problem, water often manages to seep under most dams, either along the contact area between the rock and concrete or in thin cracks and joints in the rock foundation. The upward pressure of this water is about equivalent to the pressure head of water in the reservoir.

To counteract the problem of overturning, dam designers include drainage systems in the dam, which tap into potential seepage paths and release the water uplift pressure. When calculating the uplift pressure at any section of a dam, the engineer must estimate the size of the seepage paths or cracks that might develop when the dam is stressed by floods or earthquakes, as well as the effect of drains in reducing the pressure. Using advanced computerized analysis, EPRI research is developing methods of forecasting crack propagation. Work is also being done

Water as an Escape

Water sports and fishing top the list of recreational uses of river reservoirs throughout the country. Man-made and natural water resources also contribute strongly to the ecology and scenic character of watersheds and thus to their value for hiking, camping, vacationing, sightseeing, and just plain getting away from it all.



on modeling the distribution of uplift pressure in cracks and the effectiveness of drains.

The other possible failure mode of concrete gravity dams is sliding. In this case, the shear strength of the concrete and rock have to be known and the cohesive forces of the dam on its foundation estimated. To determine typical values of these parameters and the condition of the concrete and rock, holes are drilled down through the dam into the rock and core samples are taken. These samples are then sent to laboratories for shear, compression, and tensile stress tests.

Because of problems reported at each stage of this process, EPRI is participating in extensive prototype testing programs at several dams. The EPRI work involves drilling, providing instrumentation, conducting independent laboratory tests, and documenting activities to provide a better data base of dam stability parameters. This data base will contain representative values for dams of different ages, rock foundations, and other characteristics, which will permit utilities to check their own site-specific data before performing data stability analysis.

For earth embankment dams, the federal regulations address possible erosion and breaching during extreme floods. To prevent overtopping even under the worst conditions, a dam owner may be required to expand the capacity of concrete-lined spillways. Some dams, however, may be designed in such a way that this expansion is difficult or impossible. To provide alternatives to raising the height of the dam (which might be prohibitively expensive or environmentally unacceptable) EPRI will participate with a group of federal agencies in a jointly sponsored research program. This program will focus on two less-expensive ways of protecting the integrity of a dam: armoring the crest with poured concrete or with an interlinked system of concrete blocks; and converting a large section of a dam into a spillway, using roller-compacted concrete.

Plant modernization

Many of today's hydroelectric facilities are more than 50 years old, and some have even been operating for a century. Because of their age and exceptional reliability, some of these plants have rather antiquated equipment and could profit from extensive modernization. Relicensing can thus provide a chance to upgrade such plants by restoring availability, automating operations, and improving overall output and performance to make better use of the water resource. Therefore, EPRI will publish three guides that can help utilities evaluate and modernize their hydroelectric plants.

In addition to their years of service, many hydro plants are further stressed by being cycled frequently to provide peaking power. Until about 20 years ago, most hydroelectric facilities were used to generate baseload power. Now, however, many utilities have sufficient baseload capacity in fossil fuel and nuclear plants, which cannot be cycled without considerable difficulty and expense. By contrast, hydro plants can be cycled easily, and a plant that can sustain only a 50-MW generating level for continuous, run-of-the-river flow may be able to provide 100 MW of power for short peaking periods.

Turbines are often leading candidates for modernization, particularly if they have been stressed by frequent cycling. Usually their performance has declined with age, in particular because of cavitation—the sudden collapse of water vapor bubbles at the surface of turbine blades, which causes pitting. Replacing a turbine runner can take advantage of recent advances in design and materials to improve efficiency and possibly increase power output. Even without replacement, a turbine runner can be made more resistant to cavitation by applying new welded overlays or special coatings.

Generators, which can fail suddenly in ways that require major repairs, are the leading cause of forced outages at hydroelectric facilities. Most such failures could be avoided by monitoring the temperature and other key physical characteristics of stator coils. EPRI has recently sponsored development of a scanning monitor that is mounted on the rotor of a generator and by using over 50 individual sensors, continuously provides data on individual stator coils.

By upgrading turbines and generators and by improving water utilization, the owner of a hydroelectric plant may be able to increase its output for a fraction of the cost of building a new facility. Capacity can sometimes be increased up to 15% and energy production, up to 10%, through such upgrading.

Another method of plant upgrading discussed in the EPRI guidelines is the unprecedented level of automation made possible by rapid development of computers, data communications systems, and instrumentation. Options range from improved operation under local control to fully automatic, remotely controlled facilities. Besides reducing labor costs, increased electronic control can help a plant operate more efficiently and optimize resource use. Although the trend toward automation is expected to continue as part of overall plant modernization, significant capital costs are associated with the installation of devices needed to operate subsystems, such as trash racks, penstock gates, and turbine inlet valves.

Relicensing strategy

The uncertainty and apprehension that have accompanied the shift in federal hydro policy were clearly evident at an April conference, The Future of Hydro, in Washington, D.C., sponsored by EPRI and the National Hydropower Association. "Hydro is being treated like nuclear waste!" charged one speaker. "They're piling one regulation onto another until we won't want to build plants anymore." A utility representative speaking from the floor said his company was considering just "giving up our license and walking away" from a hydro site. Another fretted privately that his small company could be bankrupted by having to build fish ladders around its aging dams.

Such deep concerns arise primarily because of three unresolved issues.

- ECPA requires that power and nonpower values be given equal consideration in granting a hydro license, but it does not specify how such balancing should be accomplished.
- The act also establishes a three-stage consultation process involving the utility and resource agencies, but dispute resolution remains ambiguous and utilities may be excluded from interagency negotiations to resolve disputes between the utilities and the resource agencies.
- Although competitors are given the opportunity to take a hydro facility away from its current licensee, no one seems to know how serious this threat may become, in practice.

Against this background, EPRI is working to provide its member utilities with the data, analytic tools, and overall guidelines they need to develop a successful relicensing strategy. "Utilities need an aggressive, proactive strategy for relicensing; they can't afford just to be responsive or passive," says James Birk. "We're particularly interested in helping them address the question of balancing power and nonpower values."

One analytic approach to this problem, developed for EPRI by Decision Focus, Inc. (DFI), was described at the Washington conference by the DFI chairman, Dean Boyd. Since any decision on a license implicitly involves a balancing of power and nonpower

R&D Deliverables

Hardware is sometimes the least of the products of research and development. Computer software and step-by-step guides are also among EPRI's new and near-term tools for dealing with federal relicensing issues on hydroelectric projects and dam safety evaluation.

Relicensing Strategies

- Assessing the value of a new hydro license. Report on the strategic issues (Vol. 1) and strategic actions (Vol. 2) involved in a typical five-year relicensing program. Due end of 1988.
- Balancing the power and nonpower values of a hydro project. Report with computer program (floppy disc) for evaluating and optimizing various factors in competing water uses at a hydro project. Due end of 1988.

Fish Protection

- *Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application* (AP-4711). An encyclopedic report of (mostly mechanical) systems that have been used to guide fish. Published September 1986.
- *Instream Flow Methodologies* (EA-4819). Evaluation of 75 models available for determining the streamflow needed to maintain the ecology downstream from hydro facilities. Published September 1986.
- Guiding migrant fish by behavioral stimuli. Report featuring mercury light attraction to safe paths through hydro facilities. Due early in 1989.
- Counting migrant fish. Report on an acoustic monitor. Due middle of 1989.
- Replenishing dissolved oxygen in the tailrace. Encyclopedic report on oxygen requirements of fish species and means of reoxygenating water from deep reservoirs. Due middle of 1989.

Upgrading Hydro Facilities

- *Cavitation Pitting Mitigation in Hydraulic Turbines* (AP-4719). A two-volume report of guidelines and recommendations (Vol. 1) and a review and assessment of cavitation (Vol. 2). Published August 1986.
- Scanning monitor to detect deterioration in windings of hydro generator stators. Prototype operating since April 1987; feasibility reported in *Rotor-Mounted Monitoring System for Hydroelectric Generators* (EL-4876), published November 1986.
- *Hydro Plant Modernization Guides.* A three-volume report dealing successively with overall plant survey considerations, criteria, and methods (Vol. 1), upgrading turbine runners (Vol. 2), and adding automated controls (Vol. 3). Due early in 1989.

Dam Safety

- Predicting and evaluating crack propagation in existing dams. Report with computer program (floppy disc). Due spring of 1989.
- Protecting embankment dams from overtopping flows. Report on techniques for "armoring" crests of dams. Due late in 1989.
- Assessing hydrostatic uplift pressures beneath concrete gravity dams. Report on equipment, methods, and how to interpret findings. Due early in 1990.
- Measuring stress, deformation, and movement in concrete and embankment dam structures and their foundations. Report on instrumentation and its use. Due middle of 1990.

Pumped-Hydro Storage

Because many of the best sites for high dams have already been utilized, most conventional hydroelectric facilities must now be constructed at low-head sites and have capacities of up to a few hundred megawatts. The only domestic form of hydropower that is still being constructed in large segments (1000–2000 MW) is pumped storage. In the United States pumped hydro now accounts for 3% of total generating capacity and is very likely to grow rapidly by the end of the century.

Part of the demand for pumped storage will come in response to deregulation of the utility industry, according to James Birk. "Deregulation may lead to less-reliable generation from independent power producers," he says. "Storage can assure customers of the continued high reliability of electrical service because of the ability to accept power whenever it is generated and then to make it available as needed. In addition, storage can provide a utility with the flexibility to purchase lower-cost energy regardless of customer demand at a specific time. For these reasons, I believe that pumped hydro could become the heart of an aggressive, deregulated utility."

One of EPRI's major contributions to this trend has been to develop more-realistic methods that utilities can use to assess the potential value of a hydro storage project, while minimizing the risks involved. In addition, research has been directed at improving the design, construction, operation, and maintenance of pumped-hydro plants. □

values, he suggested that it would be worthwhile to make the trade-offs explicit. This way, all alternatives could be compared on a consistent basis, and the one that maximizes the overall value of a hydro resource, including all aspects, could be chosen.

As an example of how the new methodology could be applied, Boyd described a hypothetical facility with a current fish survival rate of only 40%. If each fish is *assumed* to be worth $50, calculations showed that the maximum value of the hydro resource, including power, fish, and recreation, would be achieved by rehabilitating the generation facility to have a fish survival rate of 80%. Alternatively, requiring a 100% survival rate would mean that the total resource would not achieve its maximum value unless fish are worth $550 each.

Applying this methodology to actual hydro facilities will, of course, entail much more complexity and uncertainty. Nevertheless, according to Boyd, the approach is useful for communicating cost implications of various mitigation alternatives and for performing "what if" scenarios. DFI is now conducting case studies with three utilities.

A further problem, not addressed by this methodology, is how changes in the number of fish killed may affect the stability of whole populations of various species. For instance, long experience has shown that some populations may be fished at rates of more than 25% a year without affecting the number of fish available the next year. Fish populations are said to compensate for the increased mortality by reproducing faster or surviving better. No reliable method is yet available to predict the compensatory capacity of a specific population, but the issue is now being studied in an EPRI project.

Twofold opportunity

Although the uncertainties that now surround various provisions of ECPA are causing utilities deep concern, James Birk says that in the long run, relicensing can provide a twofold opportunity:

"First, we have to recognize that a good relicensing strategy not only may divide the economic pie differently among power generation, fisheries, and recreation. It also can expand the pie. The value of each component can be enhanced. And by working more closely with natural resource and environmental groups to protect their interests, utilities can gain public relations value from people who might otherwise just condemn a facility as a fish chopper.

"Second, by installing a new turbine runner or refurbishing a generator, a utility may be able to add capacity for tens to hundreds of dollars per kilowatt. That's a bargain! Upgrading existing hydropower is often the cheapest, least environmentally destructive way for a utility to add capacity to its system. We must not lose sight of that fact during the current difficulties." ■

Further reading

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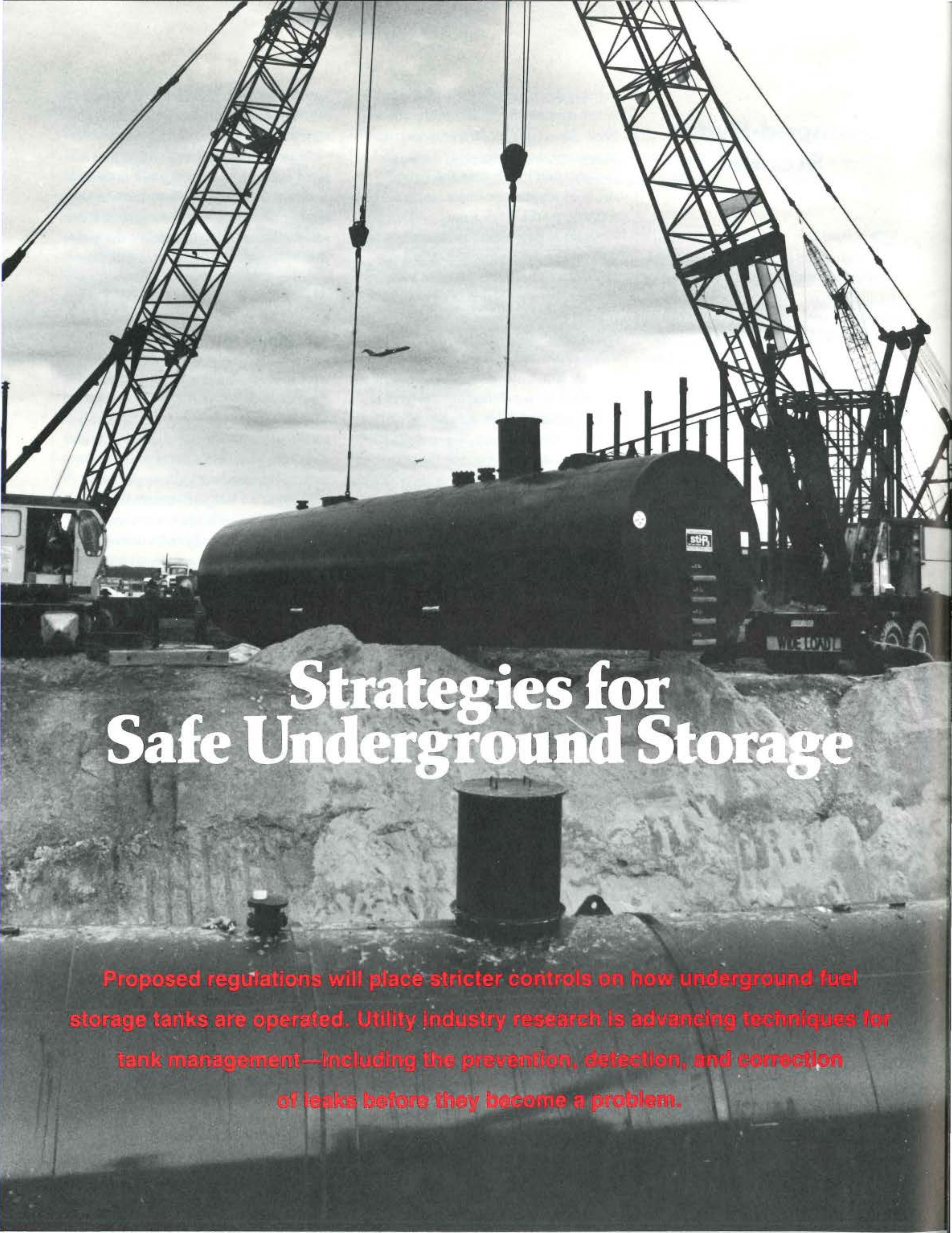
This article was written by John Douglas, science writer. Technical background information was provided by James Birk and Charles Sullivan, Advanced Power Systems Division. Additional information was provided by Jack Mattice, Environment Division, and by Dan Rastler and Douglas Morris, Advanced Power Systems Division.



Strategies for Safe Underground Storage

Proposed regulations will place stricter controls on how underground fuel storage tanks are operated. Utility industry research is advancing techniques for tank management—including the prevention, detection, and correction of leaks before they become a problem.

The practice of storing fuel in underground tanks evolved with the automobile, and as motor vehicles grew into the fabric of American life, the tanks became as common as the service stations that sprouted across the country. Tanks were originally put underground to prevent fires, to use the land surface more efficiently, and to guard against theft or vandalism. Steel was used for construction because it was readily available and offered the structural strength needed to contain large volumes of fluid. It also corroded eventually, but back in more casual times when gasoline cost two bits a gallon and the effects of pollution were not well understood, a leak was perceived as an inventory loss rather than an environmental risk.

Many industries, including electric utilities, have used underground storage tanks (USTs) for years to store petroleum and chemical products and have been generally free from environmental regulations. In the late 1970s and the early 1980s, however, that started to change amid concern that the purity of the nation's groundwater was being threatened by a variety of undesirable substances. During this period, Congress enacted several pieces of legislation aimed at protecting groundwater, a resource that provides drinking water to more than half the country's population. Evidence that leaking underground storage tanks are a source of groundwater contamination has made them the target of environmental regulations that are now forcing UST owners to make extensive—and expensive—changes in the way they use their tanks.

According to the U.S. Environmental Protection Agency (EPA), there are between three and five million USTs in the United States. An estimated 100,000 of them are leaking, and another 350,000 may soon be leaking, especially older tanks made of bare steel that are not protected from corrosion. The majority of USTs are owned by oil companies and are buried beneath neighborhood service stations. The chemical manufacturing industry also operates a significant number of underground tanks.

The electric utility industry operates an estimated 16,000 USTs—less than 1% of the national total. According to an industry survey conducted by the Utility Data Institute in 1985, individual utilities owned an average of 63 tanks, ranging in capacity from 100 to 40,000 gallons, although some larger companies owned more than 200. Utilities use these tanks primarily to store gasoline and diesel fuel at vehicle service centers, which are similar to retail gas stations, with a small fraction of tanks used for temporary storage of waste oil and solvents. Using underground tanks at service centers allows a utility to buy fuel at wholesale prices, saves labor costs, and provides a reliable source of fuel during emergencies or shortages. As in the case of retail gas stations, the tanks are buried for safety and to make more-efficient use of the limited aboveground area.

Regulating underground tanks

In 1984 Congress amended the Resource Conservation and Recovery Act to create a federal program to regulate underground storage tanks. The amendments directed EPA to propose a set of standards for USTs that would detect, prevent, and correct the damage caused by leaks. Final standards and regulations are scheduled to be issued either late this summer or in the early fall, following a period of public comment. The proposed standards would apply to the design, construction, installation, and monitoring of new tanks and require existing tanks to be upgraded to the new-tank standards within 10 years. Owners must also register their USTs with local agencies, pay for upgrading existing tanks, and assume financial responsibility for cleaning up leaks, as well as for third-party damages resulting from leaks. The regulations also allow individual states to establish their own UST programs, provided they satisfy the federal program objectives. In fact, the UST programs in some states and localities are now much stricter than their federal counterparts.

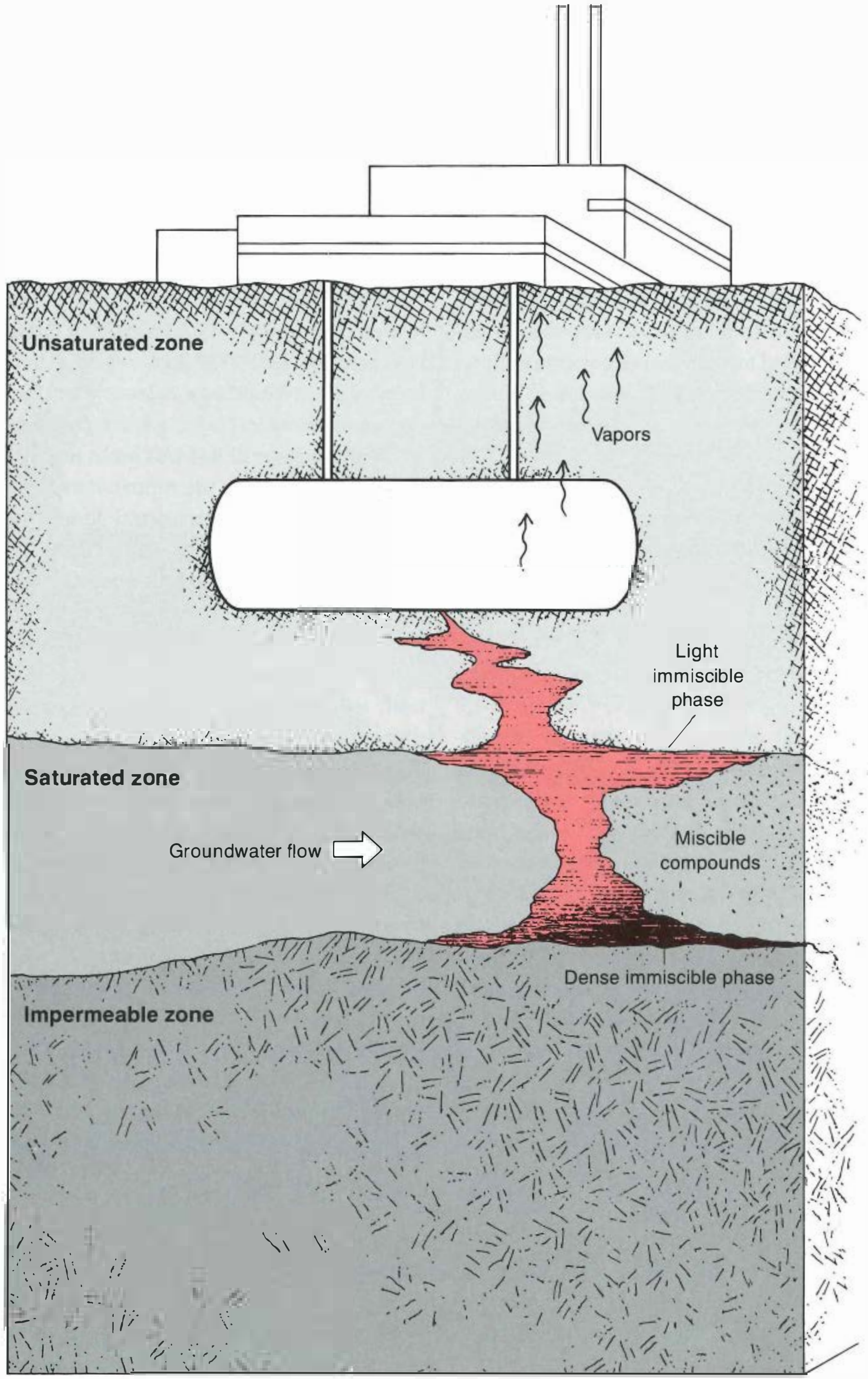
Complying with these regulations will force tank owners to make significant capital expenditures, both for new tanks and to retrofit tanks already in the ground. Although compliance is expensive, noncompliance can cost even more. The price of cleanup typically runs $200 to $400 per ton (about a cubic yard) of soil. Even small cleanups sometimes carry a six-figure price tag, and costs can soar into the millions if groundwater is contaminated.

Perhaps the most comprehensive information on leaking underground tanks is contained in a 1987 EPA report, *Summary of State Reports on Releases from Underground Storage Tanks,* which pulls together data from 12,444 UST leaks in all 50 states. According to the report, corrosion of steel tanks and structural failure of fiberglass tanks were the dominant causes of leaks in the documented cases, followed by loose fittings and improper installation. Structural failure can have many causes, including poor installation, external loads from vehicles, frost damage, a vehicle striking a gas pump, or a rising water table. Just digging up a tank can cause a leak, and sometimes tanks even get punctured by the big dipsticks used to measure their contents.

Depending on the acidity and moisture content of the surrounding soil, underground tanks made of bare steel may begin to corrode and leak in from 2 to 20 years, according to EPA, whose documentation shows that most leaks occur around the 17-year mark. The proposed regulations require new tanks to be constructed of noncorrosive material (such as fiberglass-reinforced plastic or steel lined with protective coating) or to be cathodically protected against corrosion. Cathodic protection reverses the electrochemical forces that cause corrosion by supplying an electric current to the tank. This can be done by connecting zinc or

Leak Migration

Understanding how hydrocarbons behave in different types of soil is an important prerequisite to cleaning up leaks. As it moves through the soil, a petroleum plume can be partitioned into constituent hydrocarbons according to their volatility, solubility, and specific gravity, thus complicating the cleanup task.



magnesium anodes to a steel tank or by applying a continuous electric current to the soil surrounding a tank. Some state or local regulations may require secondary containment, which can mean using an impermeable liner under the tank, providing a double-walled design, or installing the tank in a concrete vault.

Most of the leaks documented in the EPA report were detected unintentionally—when someone smelled vapors in drinking water or saw signs of escaped liquid in excavation holes. But by the time leaked fuel triggers a person's sensory apparatus, hundreds or thousands of gallons can escape into the environment. Even a tiny corroded spot on a tank wall can inconspicuously seep enough fluid into the soil to eventually cause aquifer damage. EPA is proposing that all new tanks have a monitoring system capable of detecting leaks in any part of the tank. Monitoring methods fall into three general categories: tank-tightness-testing devices or methods, inventory control, and external leak detection.

Tightness testing usually involves making volumetric measurements of the tank's interior and its associated piping. A small-diameter graduated tube, called a standpipe, is installed in the tank's filling port, and the tank, including the standpipe, is completely filled with fluid. A drop in the standpipe's fluid level over time indicates a leak and provides a means by which an inspector can calculate the rate of fluid loss. Tightness testing is affected by variables that can cause false positive or false negative results. Thermal expansion of the tank contents, air pockets, or errors in measuring fluid levels can easily cause false results in a tank tightness test. For this reason, tightness testing should be performed by a skilled technician and is often used in combination with inventory monitoring, performed either manually with a dipstick or by an automatic gauging system that measures fluid input and output and fluid levels.

External leak detection systems sense

escaped vapor or liquid in the soil around the tank, at a sump installed in an interception barrier, or in the interstitial space between the walls of a double-walled tank. As a result of the monitoring requirements in EPA regulations, many new leak detection systems are becoming commercially available—from a variety of chemical sniffers that smell vapors to ultrasonic sensors that listen for bubbles escaping from a leak.

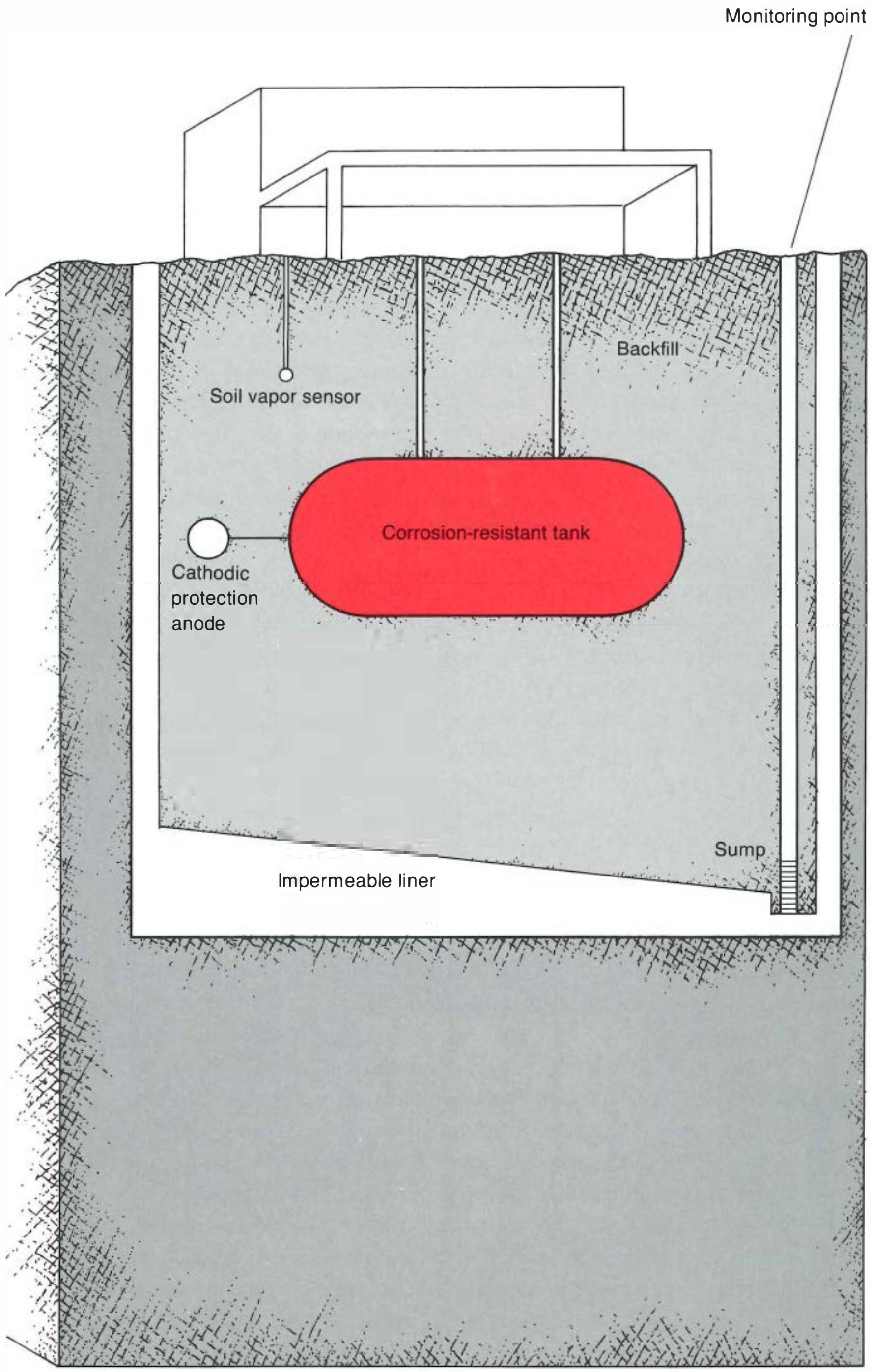
Soil characteristics and hydrocarbon behavior

One part of EPRI's UST research is directed at developing a better understanding of how leaked hydrocarbons naturally disperse, attenuate, biotransform, or travel through the subsurface environment. The cost of cleaning up contaminated soil and water is directly related to the movement of fuels controlled by the behavior of organic compounds (hydrocarbons) in the soil-water environment. Petroleum fuels are complex mixtures consisting of hundreds of different hydrocarbons, each with its own physical and chemical characteristics. "Solubility, adsorption, volatility, and specific gravity all affect a compound's behavior in the environment and, together with soil characteristics, play a large role in determining the choice of which remedial technologies to use," says Ishwar Murarka, a program manager in EPRI's Environment Division.

As a contaminant plume migrates through different soil strata, some compounds will quickly vaporize to travel vertically or horizontally through the pores created by soil particles; some will adhere to soil particles, while others continue to travel through the pores between particles. The plume will move rapidly through sandy, porous soils, while clayey soils can physically contain small leaks. If the plume reaches the water table, some compounds will float on the water's surface, whereas others will dissolve and move with the flowing water. Thus a cleanup method that

Installing Tanks to Prevent Leaks

Preventing and detecting leaks have become prime concerns in the design, construction, and installation of underground storage tanks. Proposed environmental regulations may require safeguards such as impermeable liners, leak detection systems, and anticorrosion measures.



works well on removing some compounds may be ineffective in removing the others, so remediation typically requires a combination of techniques.

Since 1986 Murarka has been directing research in EPRI's EBOS (environmental behavior of organic substances) project in the Land and Water Quality Studies Program. A major goal is finding rapid and reliable methods for field sampling and chemically analyzing affected soils to measure the quantities and concentrations of different organics. "One of the biggest challenges is finding where the hydrocarbons are and the extent of the soil and water contamination," he says. Obtaining data on contaminant concentration and migration is a crucial preliminary step in cleanup because it provides a map of the contaminant plume in the soil, as well as a means to verify the effectiveness of remediation.

One of the EBOS projects is evaluating a technique called supercritical fluid extraction (SFE), which uses carbon dioxide under high pressure and temperature to quickly separate contaminants in liquid form from a soil core sample. The extracted liquid is then analyzed by using a gas chromatograph to identify the organic compounds and their concentrations.

The SFE system and the gas chromatograph together form a portable unit that can be used in the field. "Getting soil analysis rapidly in the field is critical during cleanups, where heavy equipment costs more each hour," says Murarka. "The SFE analyzer looks very promising in this application, and there is a real chance for commercialization of a field-portable system."

To expand the data on the way compounds migrate through soil, the EBOS project is conducting experiments by using laboratory soil models. In 1989 research will focus on making field measurements of soil and water at a leaking storage tank site. "First we'll make measurements of the chemicals that have already leaked to determine what compounds are moving and how and where they are moving. Then we'll introduce environmentally safe tracers to conduct controlled experiments. The data we obtain will help us develop more-reliable methods to determine the nature and extent of contamination. There is a lot of guesswork involved in this area right now."

Cleaning up

Research on remedial technologies is led by Mary McLearn, a project manager in the Heat, Waste, and Water Management Program at EPRI. Project results have been published in *Remedial Technologies for Leaking Underground Storage Tanks* (CS-5261), which describes and compares techniques for controlling environmental damage produced by leaking USTs. The remedial technologies range from the mundane to the exotic, and each has advantages and limitations. Some of the methods stimulate natural processes that remove hydrocarbons from soil or convert them into environmentally benign forms. A technique called in situ volatilization, for example, encourages gasoline's tendency to vaporize by pumping heated air into affected soils through a network of injection pipes. A series of vent pipes then collects the fuel vapors and draws them off to a recovery unit, which typically uses activated carbon to trap the fuel vapors. This method has proved effective in removing volatile organic compounds, especially from permeable soils with low moisture content, and has the added attraction of being relatively inexpensive.

Biodegradation has been successfully used to convert hydrocarbons in soils and groundwater into innocuous compounds. Various microorganisms naturally present in the ground can oxidize hydrocarbons, breaking them down to carbon dioxide and water. Adding oxygenated water enriched with nutrients, such as nitrogen, phosphorus, and minerals, to petroleum-laden soil or water can stimulate the growth and activity of these microbes. Here again, many environmental and chemical factors act together to determine the effectiveness of the method, underscoring the importance of acquiring a solid base of site-specific soil and chemical data. For example, the solubility and concentration of the target compounds are critical in biodegradation. Most microorganisms require moisture to live and more effectively metabolize compounds that are water soluble. If the concentration of the target compound is too low, the microbes may not metabolize it, favoring another compound present in higher concentrations. If the concentration of the target compound is too high, however, it may be toxic to the microbial community.

Petroleum can also be removed from the environment by leaching the compounds down to the groundwater, then pumping out the water downstream from the leak site. The process usually involves injecting a surfactant into the affected area and installing a recovery well and pump system to bring the groundwater-leachate mixture up to a storage pond, where the surfactant is recovered.

Contaminants can also be physically isolated or contained to separate the affected area from the rest of the environment. This is accomplished by installing slurry walls or grout curtains to impede the lateral flow of groundwater, either directing the flow of water around a spill site or confining contaminated water to a specific region. The spill zone is usually capped with an impermeable barrier to prevent the infiltration of rain or surface water that would leach contaminants further into the ground.

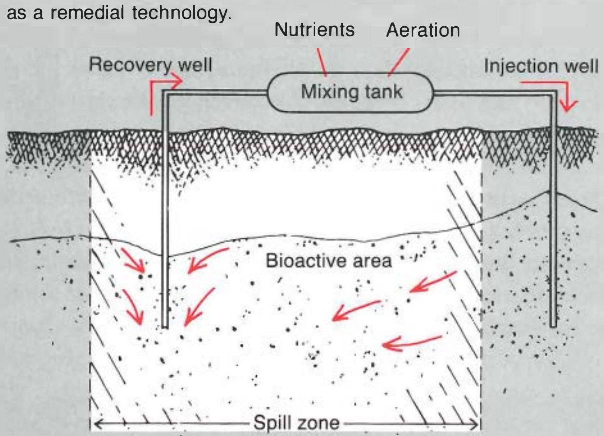
A more radical approach, which holds promise for hotspots (small spills with high contaminant concentrations), involves treating the affected soil with electric current. Called vitrification, the process melts the soil into molten glass, destroying or encapsulating the target compounds as it cools into a solid, inert mass.

Cleaning Up Leaks

There are numerous ways to correct the damage caused by leaking tanks, either by removing the contaminant from the environment or by physically confining it to a specific area. The choice of which remedial technology to use depends on a host of site-specific factors, including the depth of the water table, the permeability and moisture content of the soil, the size and concentration of the spill, and the degree to which personnel are exposed to the contaminant.

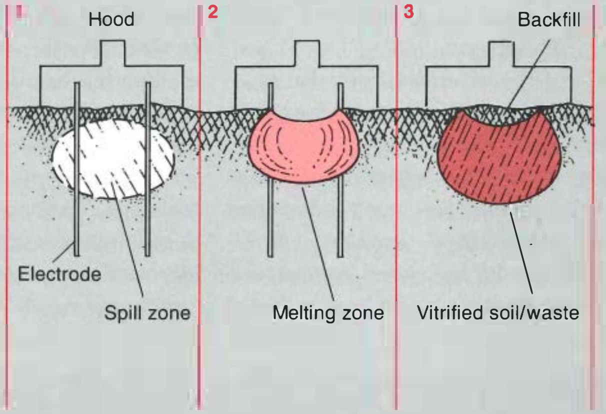
Biodegradation

Many microorganisms that are naturally present in soil can metabolize hydrocarbons into environmentally benign forms. Adding nutrients and oxygen to affected soils stimulates the growth and activity of these microbes. Biodegradation has been used successfully to break down hydrocarbons in soil and is receiving increased attention as a remedial technology.



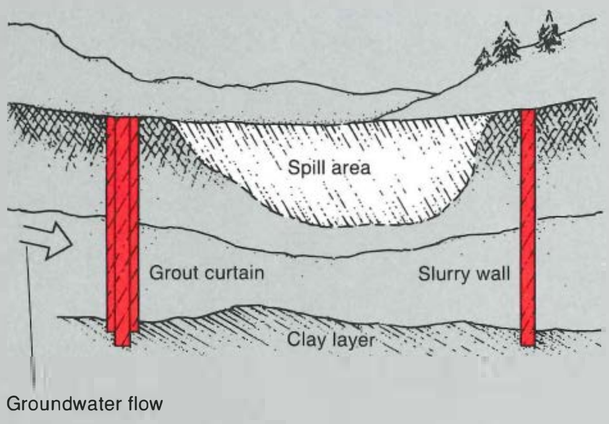
Vitrification

Small, highly concentrated spills may be treated by using electric current to superheat the affected soil into molten glass. The contaminants are either burned off in the process or are trapped as the molten soil cools into a solid inert mass.



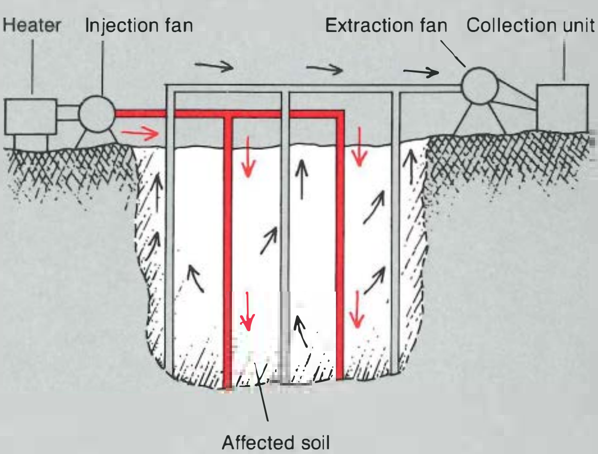
Isolation

A spill can be confined to a specific area by physical barriers. Grout curtains and slurry walls can be used to prevent groundwater from entering or leaving a spill zone, isolating the contaminants from the rest of the environment.



Volatilization

Petroleum's volatility, or tendency to vaporize, can be enhanced by pumping heated air into the affected soil through a network of pipes. The petroleum vapors can then be drawn off to a collection unit.



Sometimes site conditions require that affected soils be excavated before they are treated, either on-site or at a remote facility. These methods are generally more expensive due to the cost of the treatment system and the heavy equipment needed to excavate and transport soil. Treating contaminated soils above ground allows the use of remedial methods that cannot be used with in-place soils. For example, excavated soil can be heated in an incinerator to volatilize or pyrolyze the contaminating compounds. Chemical extraction, which involves washing excavated soil with mixtures of solvents and surfactants, is more effective when excavated soils are freely mixed with solvents.

Some of the emerging remedial technologies that are now in research and development or pilot testing may prove to be cost-effective and efficient treatment methods. Techniques being developed include supercritical leaching, which uses fluids under high pressure and temperature to leach organics from soil, and electrically heated fluid wall reactors and infrared incinerators that pyrolyze organics.

Tough choices

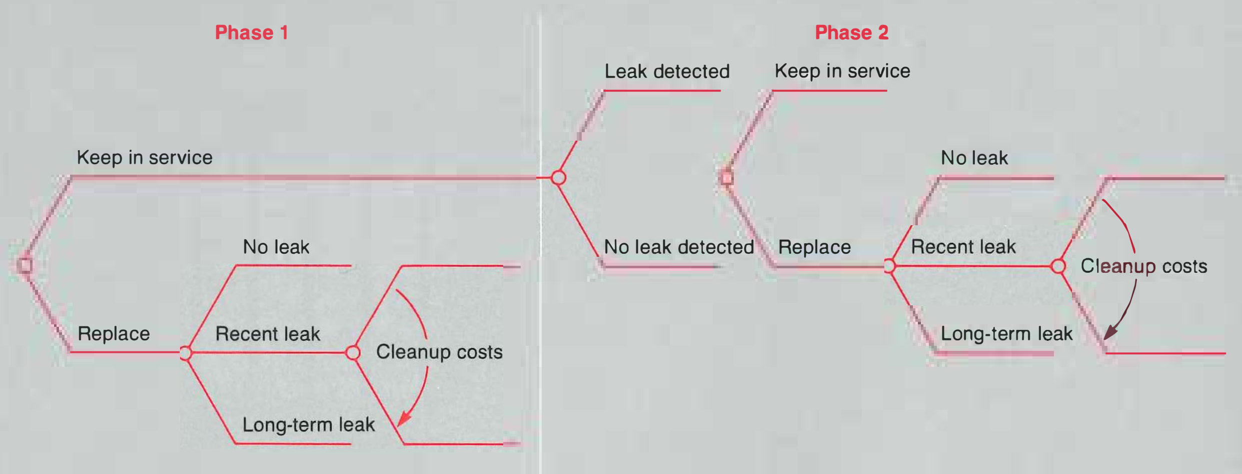
The tank management problem is challenging, not just because of the large number of tanks but because each tank site presents a unique combination of factors that confronts its owner with an array of alternatives in complying with the new regulations. The type of tank, its construction and age, the corrosivity and permeability of the soil, depth of groundwater, population density, stringency of local regulations, and the volume of fuel used at the site—these and many other factors must be weighed by managers seeking to obey the law.

"Determining the best approach to take with an underground tank depends on many site-specific factors," says Mary McLearn. "Perhaps the biggest challenge in tank management is getting the right information needed to choose confidently among all the available options." McLearn's project team is producing a series of reports that describe the state-of-the-art in tank management technologies. One examines trends in state and local UST regulations. Others describe and compare remediation techniques and advanced monitoring technologies. A fourth report, describing repair and retrofit of existing tanks to bring them up to new-tank standards, is scheduled for publication this summer. The technical reports cover their subjects in sufficient detail to acquaint readers with the various alternatives available and to suggest a course of action best suited to their particular situation.

After getting a solid base of information on all the legislative and technical aspects of operating USTs, a tank manager will want to choose a strategy that is cost-effective. "Environmental managers may hear horror stories—which actually are atypical—about undetected leaks and huge cleanup costs," says Victor Niemeyer, a project manager in the Environmental Risk Management Program

Decision Support for Tank Owners

The computer model TANKS helps utilities select an optimal tank management strategy through a decision tree structure that represents alternative courses of action and their probable outcomes. Given data that characterize a particular tank site, TANKS determines whether to replace the tank and calculates the tank's life expectancy, the probability of a leak, and the expected costs and effects of a leak.



in EPRI's Environment Division. "In response they vow to do everything possible to prevent leaks." One way to do this is to dig up all underground tanks immediately and replace them with state-of-the-art designs equipped with the best monitoring systems money can buy. In many instances, however, such an approach is unwarranted, yielding little additional environmental protection at enormous cost. "The key for utility management," says Niemeyer, "is to develop a tank management strategy that complies with the regulations in the most cost-efficient manner."

Niemeyer's project has developed a computer-based decision model called TANKS that addresses the economic and regulatory aspects of tank management. TANKS allows tank owners to select an optimal strategy for preventing and detecting leaks at specific tank sites by taking into account the unique characteristics of each site.

The program uses a decision tree technique to represent the series of testing and replacement alternatives confronting a tank owner and evaluates them on an economic basis. With the program running on a personal computer, an operator inputs data for a specific tank, including its construction material and age, the permeability and corrosivity of the surrounding soil, the potential costs of a leak, and other information pertinent to the particular tank site. In return, the program calculates the probability of a leak occurring over a specified planning horizon, recommends when the tank should be replaced, and determines the best testing method, monitoring technology, and type of replacement tank for the specific situation. In addition, the program computes tank life-cycle costs for each option and the costs of dealing with a leak.

TANKS has been distributed to more than 110 utilities. One of its first users was the Leaking Underground Storage Tank Committee of the Utility Solid-Waste Activities Group (USWAG), which used it to review alternative tank management policies concerning frequency of testing, replacement of existing tanks, and selection of new tanks. USWAG, which conducted the review to support its comments to EPA on these policies, analyzed thousands of scenarios that covered various types of tanks, tank age, likelihood of leakage, possible site risks, and strategies for testing, monitoring, and replacement. The initial results of the analysis revealed that leak costs, including the costs of remediation, are often a significant fraction of tank life-cycle costs. USWAG concluded that for this reason, the optimal strategy must take the tank site characteristics into account, especially the potential cost of a leak at the site. This cost determines the optimal amount of testing and monitoring, as well as the value of installing a more expensive and more leak-resistant tank. Replacing tanks at an arbitrary fixed age is thus not an optimal strategy, USWAG found. A policy that all tanks be replaced at 20 years of age, for example, can cost 50 to 100% more than the optimal, site-specific strategy.

TANKS is a very powerful and flexible program and provides an accurate analysis tailored to particular tank locations and circumstances. "For those who want a quick approximation of a TANKS analysis, we developed QuickTANKS," says Niemeyer. Whereas TANKS is more accurate and has great flexibility, QuickTANKS is easier to use, and it delivers results rapidly. QuickTANKS draws on the results of hundreds of scenarios already analyzed by TANKS. The program asks a simple series of questions, matches the responses with the most similar stored scenario, and reports the result.

Although its results are not as closely tailored to individual cases, according to Niemeyer, in most cases QuickTANKS responses closely match those of the more powerful parent program.

Although TANKS and QuickTANKS are enjoying widespread use in the industry, Niemeyer is quick to point out that they are no substitute for management judgment. "In developing these decision models our goal is to give managers the tools to help them make good choices and explain those choices to others," he says.

The cost of business

The casual attitudes that marked the heyday of the motor vehicle, when leaked fuel was considered lost inventory tallied at 25¢ per gallon, have given way to serious economic concern over cleanups costing $250 per gallon recovered. It is clear from the pattern of regulatory trends and growing public concern that utility environmental managers will have to change the way they manage underground storage tanks. Under the spotlight of environmental agency scrutiny, tank owners must confront the challenge of developing a careful tank management strategy that cuts the risk of leaks at minimal cost. By building a solid foundation of information on all aspects of tank management and developing the tools to make confident decisions, EPRI is helping utilities minimize the uncertainties that come with playing a high-stakes game with new rules. ■

Further reading

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Trends in State and Local Underground Storage Tank Regulations. Final report for RP2795-1 prepared by Roy F. Weston Inc., December 1987. EPRI CS-5520.

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Remedial Technologies for Leaking Underground Storage Tanks. Final report for RP2795-1 prepared by Roy F. Weston Inc., July 1987. EPRI CS-5261.

This article was written by David Boutacoff. Technical background was provided by Mary McLearn, Coal Combustion Systems Division; Ishwar Murarka and Victor Niemeyer, Environment Division.

How long can a power plant maintenance worker spend in a high-temperature area without suffering from heat stress? A newly commercialized personal monitor enhances safety and productivity by letting workers know when they've had enough.

Heading Off Heat Stress

The worker's body gets hotter and his heart beats faster. He may experience such symptoms as dizziness, nausea, and other discomfort, which warn him to put down his tools and cool off. But at other times the symptoms may be less obvious, or he may not recognize the seriousness of what he is feeling. In severe cases, he may lose consciousness. In extreme cases, fortunately very rare, he may lapse into a life-threatening coma.

The condition is called heat stress, an overheating of the body that can adversely affect workers in utility power plants and many other industrial and military environments. Different factors contribute to this potential hazard, including the heat and humidity in the work area, the amount of time and exertion involved in a job, and the need to wear special clothing that can prevent sweat from evaporating and keep heat trapped close to the skin.

Nuclear power plant workers, who often don two or three layers of protective clothing to guard against radioactive contamination, compose one of the most susceptible groups. Wrapped in their protective gear, they perform maintenance in the containment building and other areas of the power plant where air temperatures (even during outages) can exceed 110°F (43°C). The plastic suits worn by nuclear workers to protect against wet contamination are especially restrictive in preventing the evaporation of perspiration and add to the risks of heat stress associated with many tasks.

To minimize these risks and improve productivity, utilities have implemented comprehensive heat stress management programs. An important element in these programs is training workers to recognize the onset of heat stress symptoms and take protective actions, such as leaving the work area. This kind of self-determination of one's condition, however, is not always a reliable means for detecting the levels of heat stress that can threaten one's safety. Moreover, highly motivated workers sometimes ignore heat stress symptoms as they work during outages on critical maintenance tasks that must be completed before plants can be returned to service.

Recognizing the potential problems of self-determination, most utilities supplement it with standard limits on the time that workers can spend on different tasks. These time intervals, or stay times, are conservatively brief, reflecting general criteria for ensuring worker safety that do not account for the varying work styles and physical responses of different individuals. Conservative stay times also diminish productivity, increasing the time and man-hours needed to complete a job and reducing the time available from specially skilled workers.

Accordingly, a utility industry technical advisory group formed by EPRI in 1983 recommended a new approach to heat stress management based on real-time monitoring of the physiological strain on workers. The advisory group members reasoned that a portable monitor, worn by the worker on the job, could provide an alert when biologic parameters, such as body temperature or heart rate indicated that the strain on the worker was reaching upper limits of safety. The monitor's warnings could enhance the workers' powers of self-determination and thus reduce risks from heat stress, expand the conservative stay times that restrict many jobs, and improve maintenance productivity.

Today, after approximately two years of development, laboratory trials, and field testing at utility power plants, the personal heat stress monitor has become a commercially available product. Manufactured under an exclusive license by Metrosonics, Inc., Rochester, New York, the new monitor has been packaged into a lightweight module that can easily be worn by power plant workers on the job, with or without protective clothing.

"Although this monitor represents just one component in an effective heat stress management program, it provides the power plant worker with a real breakthrough in determining whether it is safe to continue working," says John O'Brien, EPRI project manager for human factors research. "This is one product that will improve both occupational safety and productivity in nuclear and fossil fuel plants, with no conflict between those two major goals."

A sensible piece of work

The new personal monitor measures both body core temperature and heart rate, either of which can indicate a level of heat stress above safe limits. Sensors for measuring these parameters are worn on a belt against the chest. A separate, pocket-size ($3 \times 4.5 \times 1$ in) processor and alert module, weighing 0.6 lb (0.3 kg), is worn outside the clothing. A thin cable links the sensors to the module.

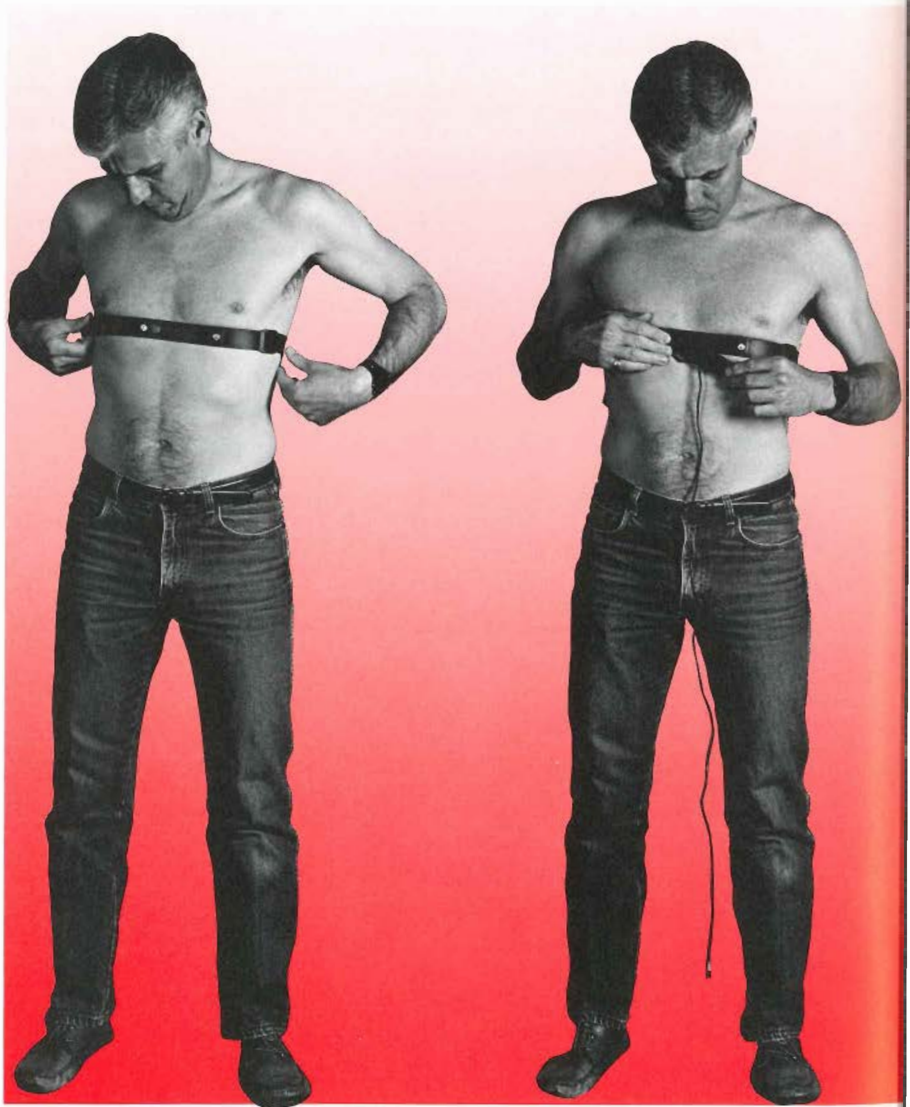
To facilitate everyday use, the personal monitor is designed to require very little training. Using a personal computer, supervisors can program the monitor to allow for the worker's age group and type of protective clothing. The worker himself, however, is not required to do programming or calculations to get a reading on his condition.

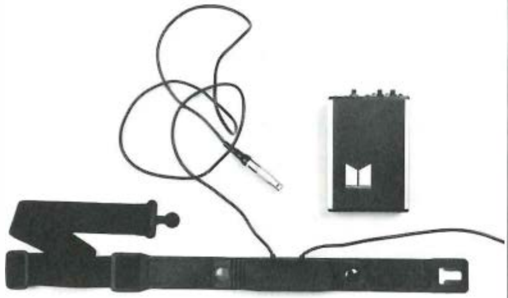
To enhance the worker's ability to determine his own condition, the personal monitor provides the worker with different kinds of warnings. There are three light-emitting diodes (LEDs) on top of the alert module, each a different color to signal a distinct alert status. A green light is the worker's A-okay, indicating acceptable levels of physiological strain; a yellow means that strain is increasing significantly but there is time to rest or take other corrective actions to reduce the strain; a red light signals the worker that it is now time to take action to reduce heat stress by securing the area and retreating to a cooler environment. In addition, an aural alarm on the monitor warns the worker of any change in alert status.

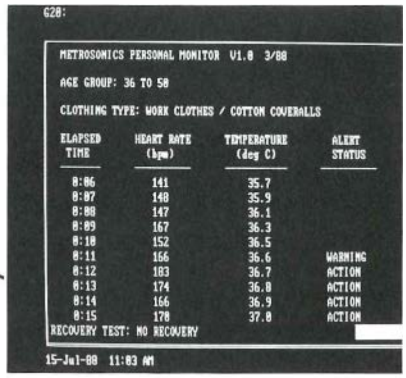
"In all cases, the personal monitor is intended as an aid to the worker's decision-making process, not as the final word," comments O'Brien. "If the worker is experiencing symptoms of heat

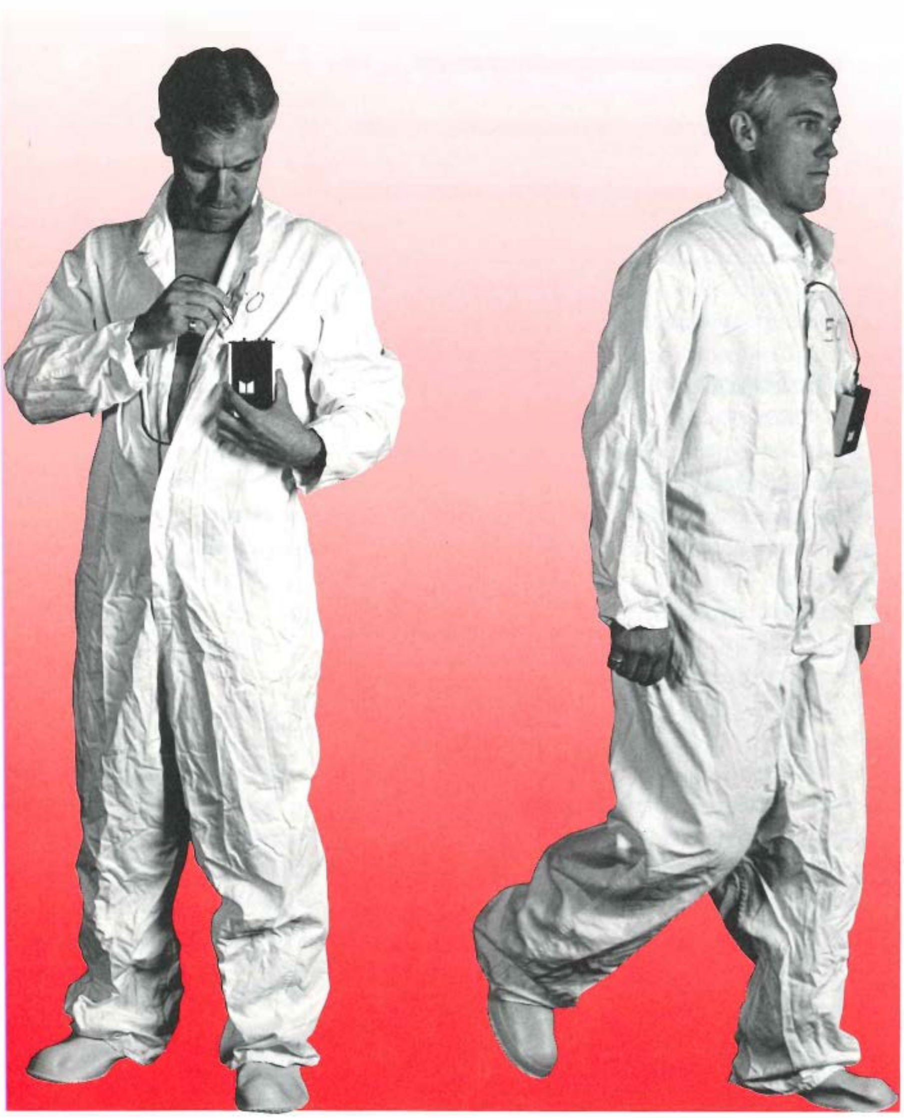
Large Capabilities in a Small Package

The EPRI-developed personal heat stress monitor, now commercially available from Metrosonics, Inc., combines processing and alert functions in a single, pocket-sized module that is worn outside the clothing. Sensors on a lightweight belt worn against the chest send signals on body core temperature and heart rate to the microprocessor-based module, which uses colored lights and a sound alarm to alert the worker to excessive levels of physiological strain. An industrial hygienist or other supervisor can use a personal computer to program the monitor to allow for variations in worker age and protective clothing. The monitor can also transfer data to a personal computer or printer for record keeping or research purposes.









stress, he must take protective action no matter what the monitor says."

Another important feature of the personal monitor is its ability to record inferred core temperature and heart rate data for later analysis. The processor module contains an output port for easy transfer of these data to a printer or personal computer, making the personal monitor valuable as a record-keeping or research tool that can help utilities track the responses of different workers to heat stress and the physiological strain associated with particular tasks.

Temperature rising

The piecing together of the personal monitor and its many capabilities was a gradual process that began with physiological studies on heat stress at Pennsylvania State University. Review of the scientific literature revealed that temperature inside the body, or core temperature, was the best indicator of the physiological strain associated with severe cases of heat stress. Researchers then identified an upper temperature limit at which to warn workers. This threshold point would be the basis of the temperature alert algorithm eventually incorporated into the monitor's processor unit.

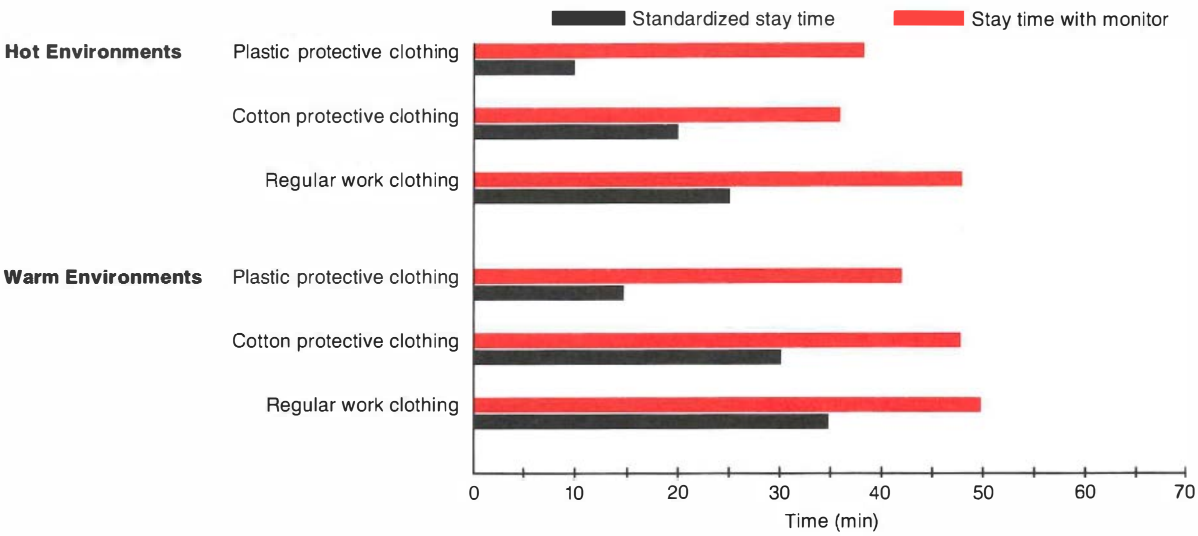
The next task facing the Penn State research team was to devise a sensor for monitoring core temperature that would be comfortable and acceptable to workers in the field. The rectal probes used in laboratory tests were clearly out of the question, as was use of ingestible thermometer-transmitters (available in both recoverable and nonrecoverable versions), tiny thermometers inserted in the ear, and other schemes alien to the culture of power plant workers. The solution was development of a unique instrument, worn under the clothes, that measures core temperature in a novel, noninvasive way.

Listen to the heartbeat

With the temperature-sensing component of the personal monitor complete,

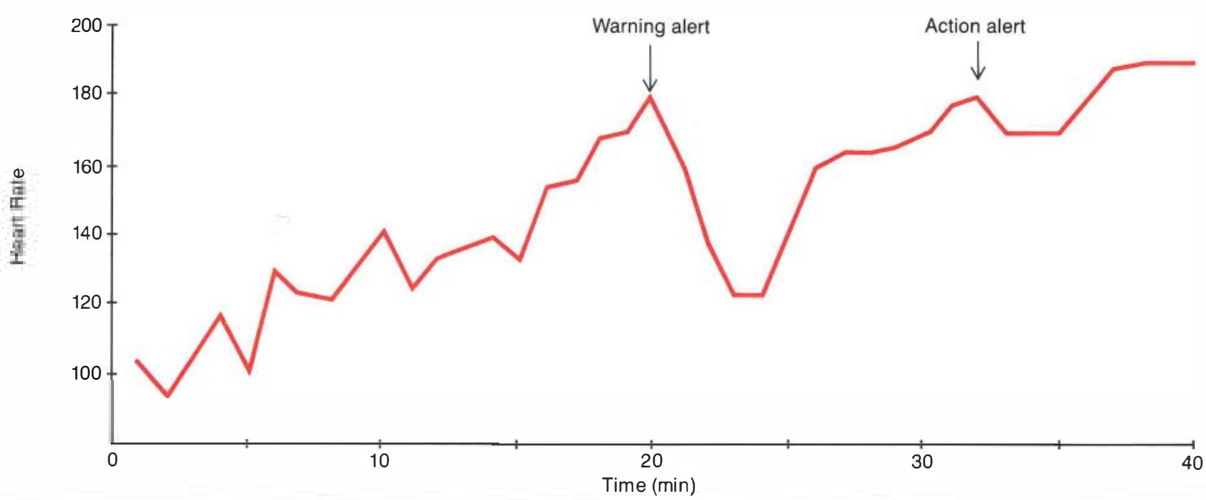
Extending Time on the Job

Since some workers are more susceptible to heat stress than others, utilities often control maintenance tasks with preset work intervals, or stay times, conservatively selected to protect all personnel. The personal monitor was designed to measure the responses of individual workers to heat stress and provide an alert when stress levels become too high. As a result, many workers can safely extend their stay time on the job, sometimes by 100% or more, depending on the type of protective clothing worn. With each individual working closer to his personal limit, productivity is improved and maintenance jobs are completed more quickly.



Monitoring Patterns of Heart Rate

In addition to body core temperature, the personal monitor follows heart rate patterns, which can also indicate excessive strain. In this example, the monitor responded to an elevated heart rate by providing a warning alert, indicating that the worker should rest for a few minutes and assess his condition. After the worker resumed work and his heart rate again rose relatively quickly, the monitor responded with an action alert, indicating that he should immediately stop working and leave the high-temperature environment.



researchers saw the potential for expanding the capabilities of the developmental product to include monitoring of the worker's heart rate as well. This dual capability, never before available in a personal monitor, would be needed to protect workers from both severe and moderate heat stress.

"Core temperature alone will indicate severe heat stress, but it's not always a reliable indicator of a more moderate heat stress that might nonetheless disable a worker," explains O'Brien. "For that you need to monitor heart rate as well."

As a new contractor in the now expanding EPRI project, Westinghouse R&D took on the complex task of designing the monitor's heart rate algorithm, along with the hardware and built-in programming for a prototype instrument. Since heart rate constantly fluctuates as workers exert themselves in different ways, the Westinghouse systems specialists had to base their algorithm on heart rate patterns established over periods of time.

"The physiological data told us that very short periods of greatly increased heart rate were not significant, but that a moderately elevated heart rate could be significant if extended over certain periods of time," says Tom Bernard, a senior engineer at Westinghouse. "Eventually we were able to design a program that could account for these factors before alerting the worker."

After designing the heart rate algorithm, Bernard and his team set about building breadboard and prototype versions of the personal monitor according to requirements established by EPRI research managers and the technical advisory group. Although bulkier than the final commercial product and built as three modules, the prototype monitor had all the same capabilities the commercial version offers today. Laboratory and field testing had to be completed, however, before EPRI and its contractors could establish just how capable the personal monitor would be.

Some like it hot

The lab tests took place in the same Penn State venue where the temperature sensor had been conceived. The purpose of these trials was to evaluate the monitor's reliability by putting it on human subjects and then seeing how well its alerts matched up to separate measurements of the subjects' temperatures and heart rates. Some of the subjects wore protective clothing of the kind used in power plants as they performed such tasks as walking on a treadmill and turning a heavy crank in temperatures as high as 131°F (55°C).

Results showed that the personal monitor was sufficiently accurate in alerting the subjects when their temperatures or heart rates went above safe thresholds. "Overall, we learned that the monitor performed well," comments O'Brien. "Subtle differences among individuals make 100% accuracy impossible; but that doesn't discount the personal monitor as a valuable aid to decision making."

A high level of reliability was also reported in field testing of the monitor at nuclear power stations around the country, including both the operating Unit 1 and the shutdown Unit 2 at Three Mile Island. Groups of GPU Nuclear maintenance workers at Unit 1 and recovery workers at Unit 2 were issued the monitors for use during maintenance and cleanup tasks, with both groups unanimous as to the monitor's accuracy and their enthusiasm for the concept. The field trials also established that the monitor was sufficiently rugged to stand up to the chemical decontamination required after some uses in nuclear plants.

"The workers immediately took to the monitors as a means for enhancing their confidence and safety," says Larry Balint, an industrial hygienist at GPU Nuclear at the time of the field tests at TMI. "There was very little of the resistance you sometimes get when you try a new technology."

A market-ready product

Having proved itself in severe conditions in the laboratory and power plant, the streamlined new product from Metrosonics appears ready for wide application in the utility industry, as well as in many other industries where people work in severe environments. The personal monitor could also serve effectively in military applications requiring protective clothing and in high-temperature environments aboard navy ships.

In the utility industry, the safety and productivity benefits of the personal monitor will be greatest when it is integrated into comprehensive heat stress management programs of the kind that have already significantly reduced the incidence of heat-related illness among power plant workers. As described in a detailed 1986 EPRI report that has helped guide the industry in this area, the most successful heat stress management programs are those that attack the problem from several different approaches. These include such engineering solutions as improved ventilation, implementation of administrative controls over work, use of special cooling garments (such as an ice vest recently developed by EPRI), and training workers to learn the signs of heat stress.

Now that the personal monitor is commercially available, utilities have a new electronic tool for protecting workers from heat stress while increasing their productivity. "This monitor is no substitute for a well-conceived heat stress management program," says O'Brien, "but it is an excellent tool of the trade." ■

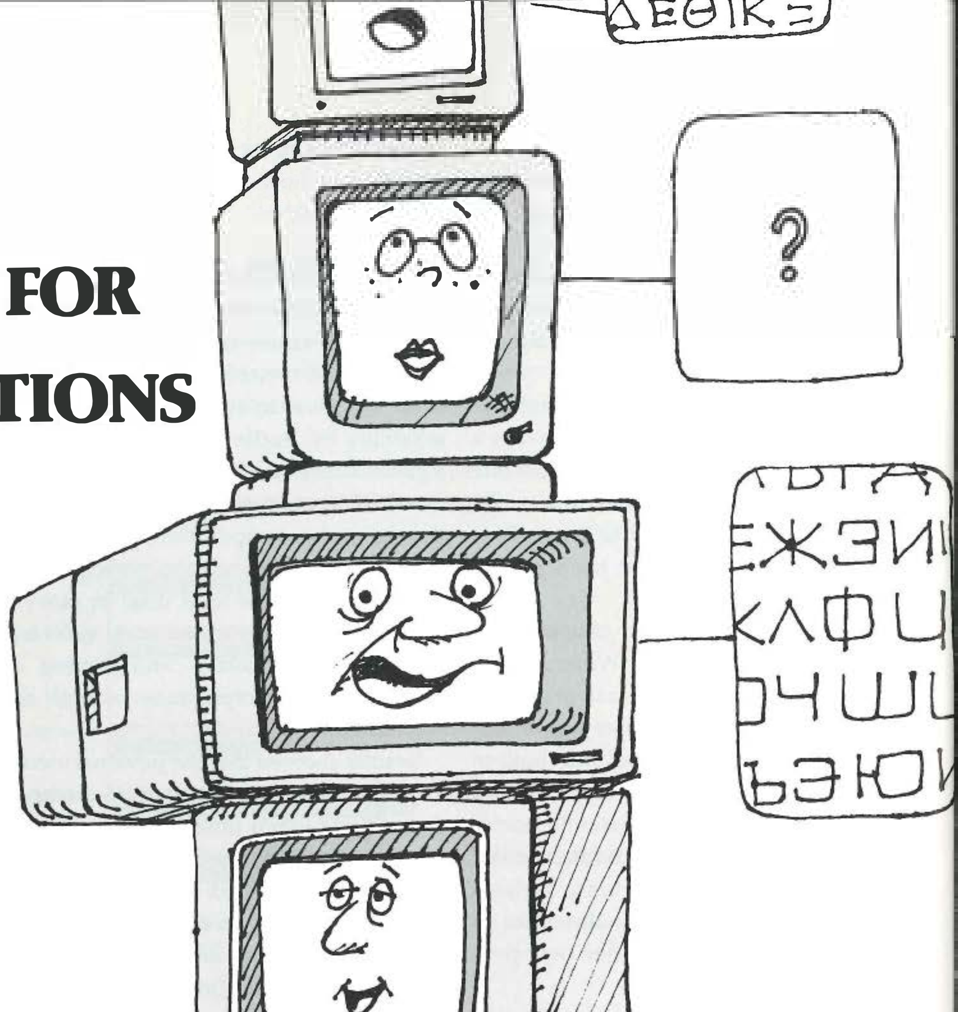
Further reading

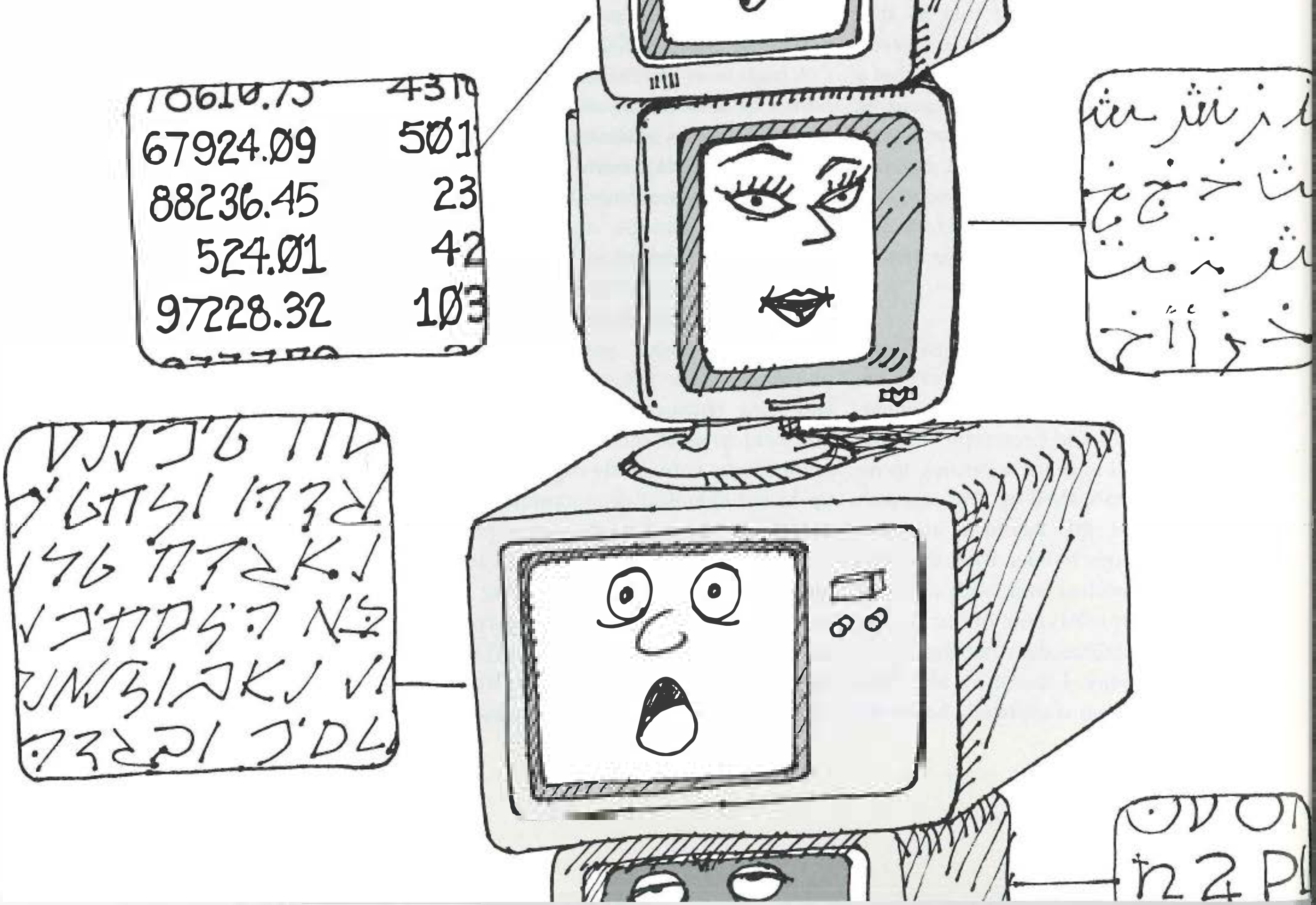
Heat-Stress-Management Program for Nuclear Power Plants. Interim report for RP2166-3, -5, -6 prepared by Westinghouse Electric Corp., February 1986. NP-4453.

This article was written by Jon Cohen, science writer. Technical background information was provided by John O'Brien, Nuclear Power Division.

BUILDING A FRAMEWORK FOR INTEGRATED COMMUNICATIONS

The modern utility relies on data from dozens of computers to operate efficiently, but many of these machines don't speak the same language. Research is under way to develop communications standards and protocols for integrating these data systems across the spectrum of utility operations.





Electric utilities are among the largest users of data of any industry and, according to some experts, are *the* largest users of real-time data. Telephones and computer workstations are on the desks of nearly everyone from the CEO to the plant maintenance technician. In addition to kilowatthours, power plants continuously generate massive data flows for internal control and coordination with other parts of the power system.

Transmission and distribution (T&D) substations, often unmanned, route and control bulk and local power flows from the highest voltages down to the neighborhood level, requiring steady streams of up-to-the-minute data. Operators aided by powerful computers in utility-wide power control centers and local distribution dispatch centers monitor and remotely control many generation and T&D functions on-line around the clock. Key data on many of these activities are routinely passed to neighboring utility and regional power pool control centers for coordination.

At corporate headquarters, managers, engineers, clerks, and specialists of every kind process and analyze business and operational information through a host of computers big and small. From next month's revenue projection to next week's system load forecast to the next day's customer billing run, data are the operational lifeblood of the utility industry.

Such a thumbnail (and far from complete) sketch of utilities' data-processing and communications functions could give the impression that all those computers and other electronic gear are neatly connected into very large systems encompassing the full range of utility operations. Information entered anywhere in the system would wind its way up, down, and across the organization to be electronically filtered out to those people and systems that need it and are authorized to receive it.

But that is far from the case. In fact, most utilities' computers and communications systems were designed only to perform specific functions, such as supervisory control and data acquisition (SCADA) in transmission or distribution operations or financial accounting in corporate systems. Most were put in place fairly piecemeal as needs arose or as new technology opened opportunities to automate. Although such independence can be a strength in certain respects, it can become a disadvantage when different systems must work together.

Most systems were installed with no—or only limited—capability to communicate with other systems. And rarely have all the systems a utility uses come from the same vendor, with compatible interconnections or standard communication protocols—the procedural codes that govern how data are exchanged among systems.

The result, say many utilities, is an electronic Tower of Babel among computers that are unable to readily talk to one another or, if they can, haven't much to say because of vastly different data base structures.

Utilities' internal operating budgets are increasingly burdened as more money is spent to design, implement, and maintain customized, often vendor-proprietary, communications links. Estimates of the industry's operating costs for telecommunications range from $2 billion to perhaps $5 billion a year, growing 25% or more each year. Few utilities may really know their communications costs because they are embedded deep within division or department budgets, even within computer capital costs. One estimate of $35 million in annual telecommunications expense for a medium-size utility may be a ballpark benchmark at best.

Many utilities and communications experts see a potential for major cost savings and productivity gains if all the various media (e.g., radio, microwave, power line carrier [PLC], leased lines) used for intra- and interutility communications could be freely mixed under an accepted set of interconnection practices and communications protocols. EPRI has already taken a significant step in this direction with successful work to automate transmission substations. Developments in other industries for integrating electronic communications, such as those in banking, airlines, railroads, or General Motors' pioneering effort to standardize factory automation protocols, also substantiate this view.

Achieving such integration over the next decade or so will require substantial R&D commitments and, more important, the active involvement and consensus of a highly diverse and increasingly competitive utility industry. But at the urging of utilities that already perceive a pressing need for communications integration, EPRI has set out on what may be a long and difficult road to this goal.

New demands in a digital world

The growing cost of telecommunications is only a reflection of the many different trends and forces that are driving utilities toward integration. Digital devices are proliferating throughout utility systems, creating new and denser data flows, often with unique communications requirements. For example, EPRI-led demonstrations in automating transmission substations and distribution systems point to a future in which a variety of communications links, including high-speed fiber-optic data paths and coaxial highways, will be part of broader digital, microprocessor-based communications and control systems. Eventually, these systems are expected to replace most of the electromechanical and electronic devices now used for protective relaying and circuit-switching.

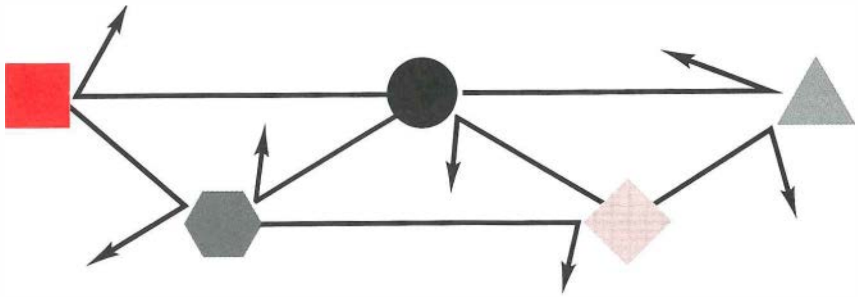
Meanwhile, utilities are reaching out to customers more than ever in promoting end-use conservation, load management, and time-of-use pricing. Many of these initiatives depend on digital kilowatthour meters and low-cost remote terminals at customer sites that transmit and receive data signals. The cost of the technology for reliably and quickly communicating to and from these devices may be crucial to the economic viability of some distribution automation functions.

To respond to competitive pressures and to avoid the costs of new generating and substation capacity, utilities are exploring ways to operate existing transmission and distribution systems closer than ever to their physical limits. This requires more and better data on equipment temperatures, line voltages, system stability, and feeder loading, for example. Independent power producers and increased regional power wheeling are likewise adding to the data communications requirements at power control centers.

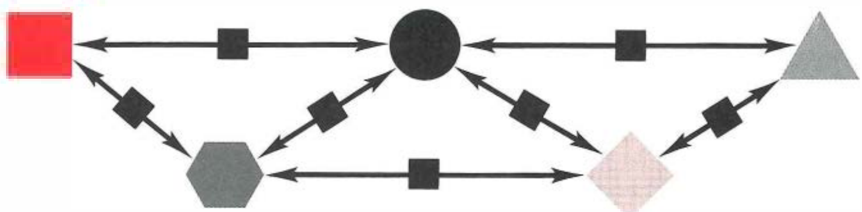
On the other hand, the media available for utility communications are changing as well. Dedicated, leased, analog telephone lines for point-to-point communications—once the mainstay for many utility power system control and protection applications—are no longer economical. For reliability and other reasons, some utilities have put in place their own microwave and PLC systems and are now increasingly turning to fiber-optic communications.

Operating at the speed of light and offering economical data communications over the long term, fiber-optic cables are nevertheless expensive to install (even along transmission lines as some utilities are now doing for communications, including system protection functions). In some cases, however, fiber optics' tre-

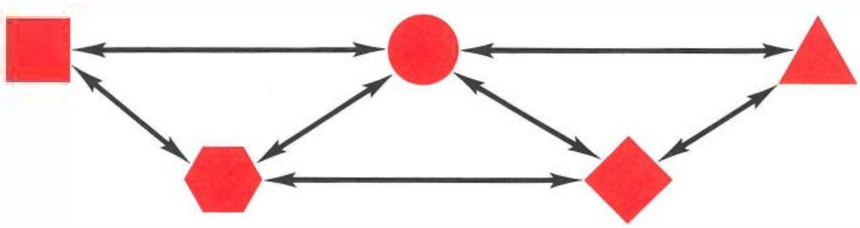
The Problem: A Failure to Communicate



Most computer systems used by utilities perform specific functions, such as supervisory control and data acquisition in transmission and distribution systems, or power plant process control, or financial accounting in corporate systems. Typically, they are not designed to freely communicate data to and from different computer systems, even within the same organization.



The Black Box Solution . . . When intersystem data communication is required, available solutions tend to be vendor- and application-specific, as well as costly. Historically, solutions have involved the creation and installation of custom hardware and software between different systems that not only provide a common interface but also translate the data codes of one system to those recognized by another. While such a black box approach can be successful, it can also create obstacles to later system expansion or lock a user into the interface solution of a single vendor.



. . . Or an Integrated Approach A more-rational, long-term solution implies communication protocols designed to a set of common, accepted standards that could meet the needs for data exchange at various levels of computer system operations. Data could flow between many vendors' equipment and operating systems without expensive black boxes or custom interfaces. Designed to work with any mix of systems and communications media, standard protocols would permit the integration of diverse data systems and provide a flexible basis for system expansion and new configurations.

mendous data capacity may be unneeded or underutilized. Some utilities are even leasing capacity on fiber-optic links to third parties.

PLC technologies are today used widely for transmission protective relaying and for load management functions and meter reading at the distribution level. PLC systems, which encode data as 30–300-kilohertz transmission signals on utility circuits, are highly reliable and generally adequate in data transfer capacity.

Utilities also employ a wide variety of radio systems for voice and certain data communications, mainly in the T&D areas, including service dispatch and emergency management. Most of these operate on UHF or VHF frequencies assigned by the Federal Communications Commission for exclusive utility use. Yet these frequency bands are already overcrowded and are limited by bandwidth, data rate, and signal range. Moreover, the last decade's explosion in the use of commercial broadcast channels for many different applications means there is little, if any, room left in the radio spectrum for expanded utility communications.

Microwave transmission, which dominated the long-distance telephone business for three decades before the advent of fiber optics, offers cost and certain technical advantages for point-to-point communications over relatively long (15 miles or more) distances. But terrain and even weather can interfere with the reliability of microwave, which requires line-of-sight paths between transmitters, repeaters, and receivers. Still, microwave communications are used extensively by utilities in T&D control.

Some utilities have begun to use commercially available satellite channels for some intercompany communications, such as videoconferencing and other applications where the typical quarter-second uplink-downlink time lag is not critical. (Some utility functions, such as transmission protective relaying, require response times 30 times faster than a quarter-second.) Channel-use charges are steadily declining as more communications satellites are launched into orbit, although the costs of earth stations and transponders are still in the clouds. But emerging technology based on very small aperture ground terminals promises to lower even those costs.

As the utility industry's data sources and flows grow by leaps and bounds and as communications technology becomes more sophisticated every year, the cumulative investment in computers and communications ratchets ever higher to meet the demands for data in a digital world. But the sums already spent are too great to just replace every system whenever a new one with added capability becomes available. Utilities are increasingly concerned that systems they install today could become orphans as vendors enter and leave the market.

Each year a greater share of the recurring expense goes toward special devices and custom software needed to interconnect systems of different makes, vintages, and technologies. And it is in this realm that utilities, like many other industries, are running into not a brick wall but a partial patchwork quilt of equipment standards and communication protocols.

A patchwork of standards

As anyone who has tried to mix and match personal computer components from different vendors soon learns, compatibility and interconnectivity are words that can invoke nightmares. Adequate and affordable protocols for mere point-to-point communication took years to evolve from computer equipment manufacturers. Protocols applicable for local area utility networks have only recently become a priority among equipment makers, but they remain largely vendor-specific and quite expensive.

Further behind are wide-area network standards for linking computer networks to other computer networks so that actual telecommunications functions are transparent to diverse users. Charting a long-term communications course through these thickets in the absence of common protocols can be a frustrating challenge.

Much of the computer equipment used by utilities is also used in other industries and is manufactured by very large vendor companies (e.g., IBM, Digital, Control Data) for a huge international market. Under the leadership of the International Standards Organization (ISO), some standards based on protocols accepted and implemented by the vendors are now in place for many of the different levels and aspects of computer networks. ISO, in conjunction with CCITT (Consultative Committee for International Telephony and Telegraphy), has developed an organizing or architectural framework for various standards under what is called the Open Systems Interconnection (OSI) reference model.

But there remain large gaps in the OSI quilt, each with its own chicken-or-the-egg dilemma of whether users or vendors define the protocols and at what point a protocol becomes an accepted standard. International politics and competition keep the standards process slow, constantly in flux, and confusing to user industries.

Some industries have, in effect, put their foot down and proceeded to define and develop their own special requirements for computer communications. Banks and other financial institutions, for example, have developed special protocols that are now standards for their intra- and intersystem data exchanges. But it is GM's effort to standardize protocols for factory automation equipment that may serve as a model for what the utility industry needs and eventually will develop.

Only within the last few years, when the automotive giant set out to automate its production lines with robots and other computer-controlled equipment, GM found that customizing the communications software to interlink these devices was accounting for fully half of the total cost. In response to what it saw as an intolerable situation, GM developed an all-encompassing approach to communications based on the ISO–OSI reference model, dubbed the manufacturing automation protocol (MAP).

Comprising a standardized set of protocols, one or more for each of the seven layers of the OSI model, MAP defines the specifications that all vendors offering equipment to GM must meet. It incorporates many ISO standards and some developed by the Institute of Electrical and Electronics Engineers (IEEE), as well as certain custom-designed protocols. Boeing Computer Services has developed a variant of MAP for office automation, called the technical and office protocols (TOP).

With the MAP–TOP architectures, user industries can plan long-term network development without being locked into a single vendor. New communications interfaces promise to be far less expensive to implement and to more closely match the needs of users because vendors will know which protocols are the accepted standards.

The MAP family of protocols have generated much interest among utility communications experts. Some suggest they are directly relevant to as much as 80% of the anticipated requirements for communications integration in the utility industry.

The missing 20% is considered unique to utility functions and probably will have to come from within the industry itself. A related step in this direction has already been taken by EPRI in R&D on transmission substation automation. After nine years of development, open specifications are now in hand for functional and communications compatibility among different vendors' digital equipment modules for protective relaying.

Broad application of new communications architectures will not come easily. There are different opinions about how much of MAP applies to utility requirements. Despite the potential transferability to utility applications, some analysts note that MAP may be limited in terms of dependability, redundancy, failure modes, media specification, and transaction speed.

On the other hand, Pacific Gas and Electric is said to have taken a pioneering step in building on MAP as the basis for its own local-area integrated communications network at the Diablo Canyon nuclear plant in California. All computers at the plant, including about 1000 workstations, are tied into the network, which is estimated to have saved PG&E over $1 million in a single month by minimizing plant downtime during a scheduled maintenance outage.

Perhaps more important than the fine points of MAP is the fact that GM managed to develop it and make it work for its purposes. Its very existence gives hope to utility communications analysts that a similar, perhaps very similar, architecture can be developed for and accepted by the utility industry.

An architecture for utilities

With all this background in mind, some 65 utility executives, computer manufacturers, expert consultants, and EPRI research managers representing the full range of utility operations gathered in Houston, Texas, in late 1986 to chart a course for the distant shore of integrated communications. From the wide-ranging presentations at that workshop and a follow-on scoping study prepared by Energy and Control Consultants, the outline of a long-term EPRI research initiative is now in hand.

Five related projects were identified for EPRI to pursue in close coordination with member utilities. The first is to develop a utility communications architecture consistent with the OSI model that would establish a comprehensive set of guidelines. Concurrently, work should begin to define a set of access procedures and formats so that computer systems within networks can automatically swap data between various data base structures.

Next, in anticipation of integrated communications in the future, there will be a need for functional specifications and guidelines for network analysis software. Such programs (and associated hardware) will be used in the planning, operations, and maintenance of wide-area utility and interutility communications networks. The fourth research area would involve implementing and demonstrating, first at pilot scale and then at large scale, the products of the first three developments at a host utility.

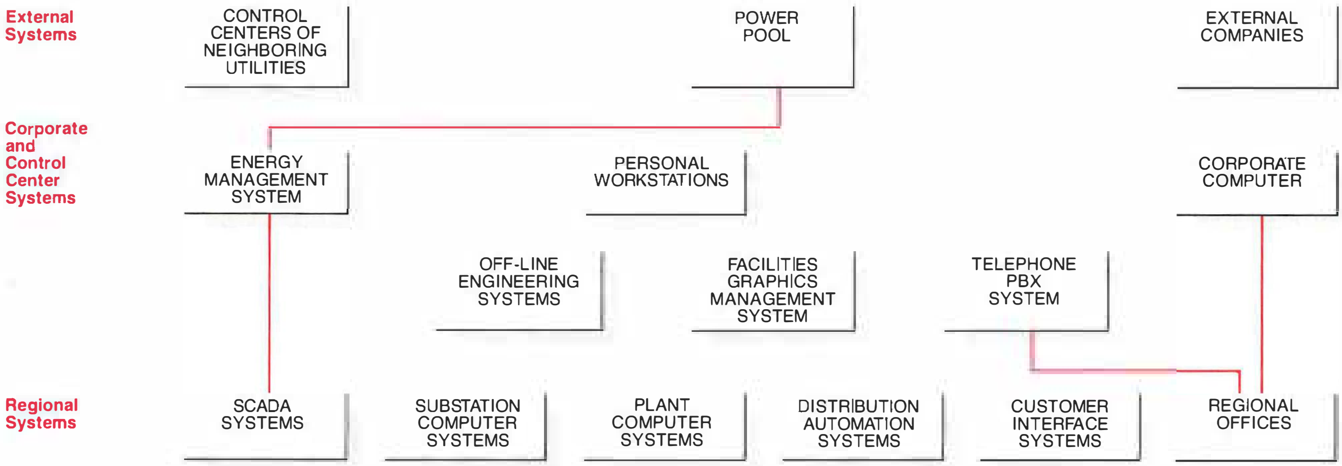
A fifth and auxiliary research need was identified for investigating the use of artificial intelligence in optimizing communications network configurations and possibly in their routine operation. EPRI and utilities are already pursuing a broad range of applications in the field of artificial intelligence known as expert systems as on-line aids to power plant operators, control center dispatchers, and other personnel. For integrated communications, however, artificial intelligence techniques are not in the near-term focus and in any case must await substantial progress in the preceding areas.

For the time being at least, the first two research areas—development of a utility communications architecture and integration of data base access procedures—are formidable enough challenges themselves. EPRI is now evaluating contractor proposals for these projects, which should get under way later this year.

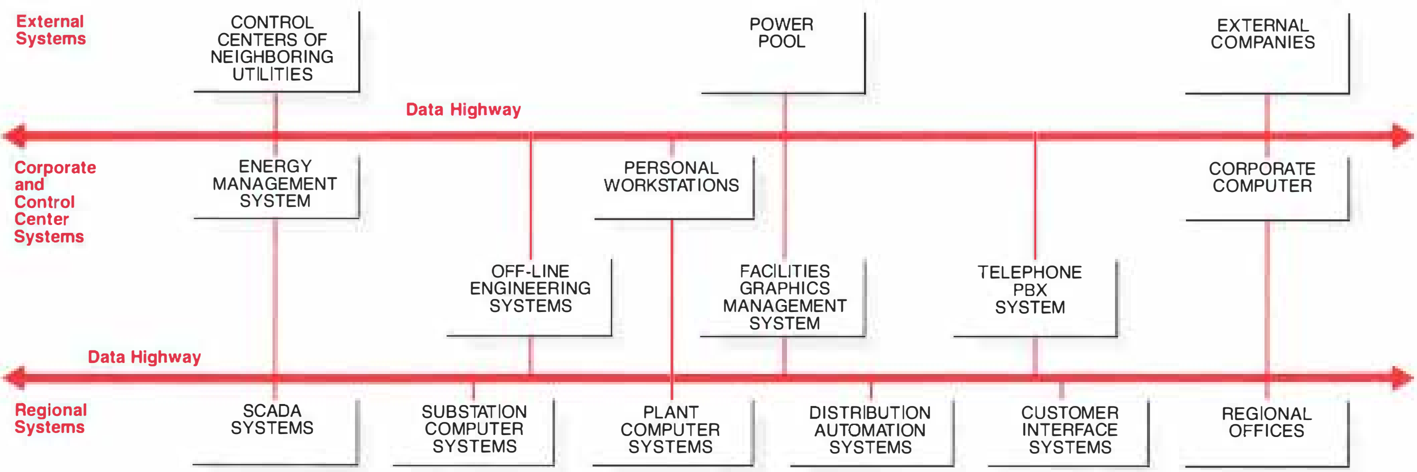
As envisioned, a utility communications architecture would encompass all communications requirements with many separate standards, some of which exist and others of which have yet to be developed. In addition to the goals of reducing communications costs and promoting interface compatibility among vendors, the project will attempt to establish

Communications for Utility Systems

Today's Environment Utilities employ a wide variety of computer systems for specific applications in three broad levels of operation within and beyond the organization. Lines indicate the typical extent of interconnection and data exchange among these systems today. Systems at the regional level (power plants, distribution dispatch centers, transmission substations, regional offices, customer interfaces) communicate with a large number of related field devices, although often by means of proprietary protocols. But from the regional level to the corporate or control center level, there are only limited interconnections. Corporate computers typically cannot communicate with the system control center or power plant computers but may readily exchange data with regional office systems. Some control center systems communicate with power pool computers outside the organization but usually are not interconnected with their counterparts at neighboring utilities. Within these levels of different systems for different applications, many islands of communication may exist. Overall productivity of the systems and the organization could be greatly improved and interconnection costs reduced if all utility communications were integrated under accepted protocols and standards.



Concept of Integrated Utility Systems Networks based on standard protocols and interconnections would form data highways linking regional systems to corporate and control center systems and linking those with external systems. Universal data base access procedures would also be key elements of an integrated system. Such an approach would allow, for example, corporate-level systems to directly access data resident in a specific plant computer or would provide a power pool computer an on-line link with utility members' control center systems. Or a utility's graphics management system for facility maps and blueprints could communicate digitized drawings directly to substations or power plants. Theoretically, any system in the universe of utility data communications could communicate with any other system.

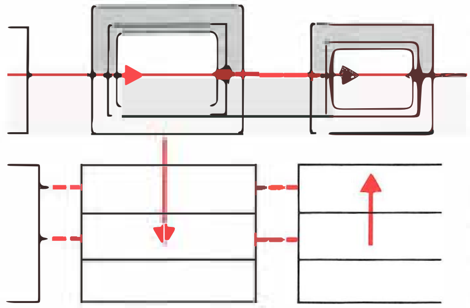


EPRI's R&D Strategy for Integrated Communications

With the guidance and close involvement of member utilities, EPRI has launched a long-term initiative to define the requirements for integrated utility communications systems in the future, identify elements that may be adapted from other industries, and develop the missing pieces to realize the potential for improved productivity and reduced telecommunications costs.

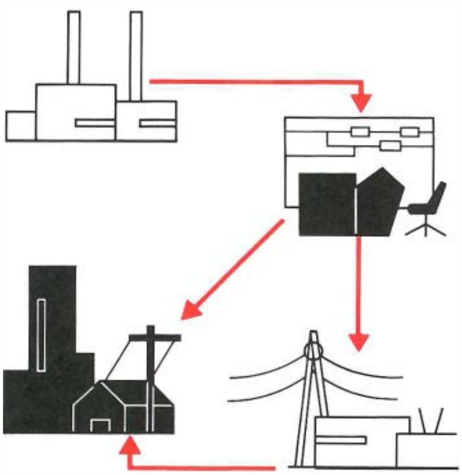
Network architecture

Separate projects are getting under way to develop an architecture, or comprehensive framework, for integrated communications, as well as procedures for making disparate system data bases able to exchange information. Work on the utility communications architecture will benefit from international standards development and work in other industries for interconnecting various process computers and control equipment, such as that represented by General Motors Manufacturing Automation Protocol.



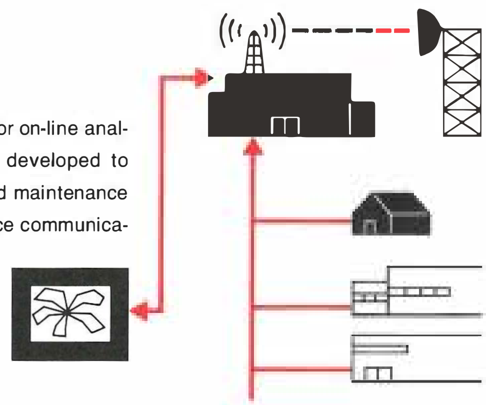
System demonstration

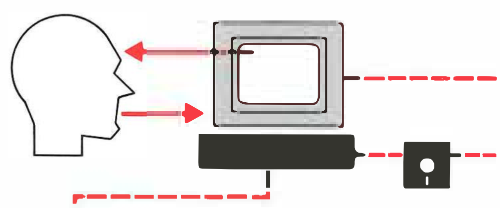
A prerequisite for utilities to embrace the integrated communications architecture and the data base access procedures is a realistic demonstration. Although details will depend on the outcome of the previous efforts, it would most likely first involve a pilot project for only a limited set of applications, followed by a full-scale demonstration involving virtually all utility operations.

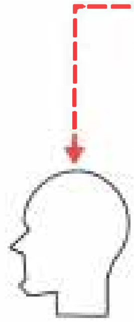


Network analysis

The capability and tools for on-line analysis and control will be developed to assist in the planning and maintenance of integrated data and voice communications networks.





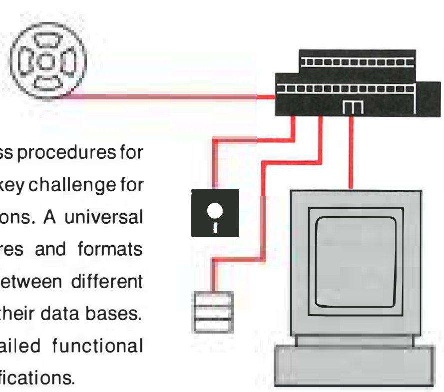


Expert systems

Ultimately, the feasibility of artificial intelligence-based expert systems will be explored for their potential in helping to plan, operate, and maintain utility communications systems.

Data base access

Standardization of access procedures for diverse data bases is a key challenge for integrated communications. A universal set of access procedures and formats would form gateways between different computer systems and their data bases. EPRI is pursuing detailed functional requirements and specifications.



the synergistic benefits that may flow to a utility from integrated communications.

With the OSI model as a starting base, the scope of the work will span all intrautility systems, including corporate business computers, workstations, SCADA systems, T&D dispatch centers, remote terminal units on distribution systems (including customer interfaces), power plants, and voice and video. Interutility communications will also be addressed, drawing on existing standards, such as those of ISO, IEEE, and major vendors, and the energy data exchange protocols recently adopted by utility members of the Western Systems Coordinating Council and the Interutility Data Exchange Committee in the East.

The initial phase of the project will extensively survey and identify utility communication requirements, investigate the capabilities of various communications media, analyze existing standards for applicability, and develop the missing links to define an ultimate, flexible framework of guidelines for standards and protocols.

If a sufficient number of utilities accept the architecture, it will be up to the industry to propose the guidelines to domestic and international standards development bodies as true standards. By that time, several years away at the earliest, many utilities may already be using the architecture in specifying equipment purchases and in system planning.

As a companion to the development of a communications architecture, the data base integration work is crucial. Users and computer programs in an integrated computer communications system cannot be expected to translate every request for data into the specific commands needed by a distant subsystem or data base. There must, then, be gateways as part of the integrated system that can address, query, and search many different data bases in the most efficient way.

In addition to developing those gateways and commands, related methods will be needed for handling issues of security (access and authorization), response times (priority and time-critical data), directory services, performance monitoring, data codes, and interface guidelines. The project is expected to develop and demonstrate specifications covering all these issues. Such specifications could then be used by vendors to interface a utility data base access procedure in future integrated communications systems.

The road ahead

It will probably be several years before results from the first two of the planned EPRI projects in communications integration are clear and point toward later implementation and demonstration in an operating utility environment. And it may be many years beyond that before truly integrated utility communications systems are in place and form a basis for national or international standards. Yet even before the nuts-and-bolts aspects of the work are under way, EPRI research managers know their work and that of others is cut out for them.

But despite the many dimensions of the challenge (technical, institutional, financial, and other), EPRI research managers and advisers already sense a convergence of opinion among utility members that concerted industry action is needed now and that EPRI is the logical place to center it.

"Utilities recognize the enormous potential in power system automation, which cannot be realized without integrated communications, and they realize that as an industry, we have just begun," says Narain Hingorani, EPRI vice president and director of the Electrical Systems Division. "They are also keenly aware that to make the power system of the future a reality, we have to change the way we do things, the way we communicate, and that means integration. If we don't start to put the pieces in place now it could be a serious impediment to system automation and, in turn, to the industry's ability to become more efficient, productive, and competitive."

Bill Boston, senior vice president at Wisconsin Electric and head of a utility member advisory committee on the communications work, sees a pivotal role for EPRI, both in an R&D sense and as an agent for technology transfer. "A key part of the effort is to understand what standards exist in other industries that could be adapted to utility use. EPRI should be able to speed that process in a broad-based effort that will benefit all utilities. What is needed may be more in the realm of development than research. I think there is enough development and technology transfer needed that it's a natural role for EPRI."

Adds Hingorani: "The projects we are embarking on will be very complex. It will not be enough just to develop something, which we are good at. We also have to listen carefully and bring the utilities together in some kind of consensus at the same time. Utilities have been asking us for help in this area, but they must also be ready to eventually accept the outcome and put it into practice. Timing and coordination will be very important, involving not just the utilities but all the equipment vendors, government agencies, technical establishments, and international organizations. EPRI has undertaken to organize this effort, which goes far beyond project management, to develop what is necessary and to illuminate a path to truly integrated utility communications systems. Well, we are on our way." ■

Further reading

"Building the Smarter Substation." *EPRI Journal*, Vol. 13, No. 4 (June 1988), pp. 16–21.

Integration of Utility Communication Systems. Final report for RP2473-14, prepared by Energy and Control Consultants. August 1987. EPRI EL-5242.

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This article was written by Taylor Moore. Technical background information was provided by Thomas Kendrew, William Kubicki, Larry Mankoff, Stig Nilsson, and William Shula, Electrical Systems Division.

TECH TRANSFER NEWS

TECHNOLOGY TRANSFER MEETING, 1988

Refining the Process and Surmounting the Barriers

No one would dispute that technology transfer is one of the essential elements in a utility's relationship with EPRI. The Institute's diverse membership, however, reflects a variety of approaches to technology transfer, different problems, and a wealth of creative solutions. Gathering in Palo Alto in May for a technology transfer meeting, more than 100 utility Technical Information Coordinators (TICs) had the chance to take a close, hard look at the technology transfer process, sharing perspectives with one another and with EPRI staff.

One point clearly emerging over the course of the three-day meeting was that EPRI, together with its member utilities, has an important role to play in making technology transfer work. "We are entrusted not just to create value but to deliver it," EPRI President Dick Balzhiser told the TICs, a remark amplified in presentations from EPRI staff on tools and activities to support the implementation of new technology.

Representatives from each of EPRI's technical divisions described the technology transfer support they provide through such mechanisms as workshops and seminars, publications, and direct response to utility requests for information and technical help. Utilities were encouraged to seek out the information they need from EPRI technical specialists, to attend workshops and other events, and to provide the Institute with feedback on successes or problems encountered with EPRI-developed technology.

In addition, EPRI staff described two valuable tools that have recently been developed to aid utilities in managing EPRI's large output of information and distributing it to the line employees who can put it to use. The TICs received a hands-on introduction to the new TICWorkstation, an integrated PC-based system that allows them to access, store, and manipulate information on EPRI R&D and related activities at their utilities. Many TICs also had their first look at the new EPRI Product Books, a reference series that describes all the Institute's delivered R&D products in a concise format that organizes the information contained in thousands of technical reports.

The Utility Role

In addition to assessing EPRI's contribution to the technology transfer process, the TICs focused on the importance of working together with EPRI to reap the benefits of their investments in the Institute. "EPRI has done a good job in providing assistance and information, but ultimately it is the utilities who must make technology transfer happen," said Chris Rolfe, Duke Power's TIC, in a lively address to his industry counterparts.

While reviewing the utility role in technology transfer, the TICs talked frankly about institutional barriers that can stall the process and offered solutions for clearing away these barriers. One barrier frequently mentioned by the TICs was a need for greater support from upper management; however, there were also many positive statements about increased management support paying off in large benefits. Rolfe neatly summarized the issue, saying, "Successful technology transfer depends on recognition at the management level that technology is important, on resources committed to technology transfer, and on expectations within the organization that individuals participate in the process."

Getting down to specifics, the TICs identified several forms of management support that can help them facilitate technology transfer. These included increased staff support for TICs, allocations of time and budget for participation in EPRI committees and events, deputizing line employees with definite technology transfer responsibilities, and the cultivation of product champions—line employees who believe in new technologies and make strong, individual efforts to see them applied. Some TICs saw the issue in terms of corporate culture, emphasizing the need for a corporate philosophy that places a high value on the implementation of new technology.

In discussing barriers to technology transfer, many TICs mentioned problems in communicating with the line employees at their utilities. As the TICs see it, the problem involves both the passing along of technical information and the need to secure the attention and involvement of line employees who are busy with everyday responsibilities. Although support

from upper management was deemed crucial to these goals, in-house publications, presentations, and other communications tools were also identified as means for overcoming the barriers. The TICs expressed high hopes for TICWorkstation as an aid for organizing information and making presentations, while others mentioned the effectiveness of EPRI's wide range of publications for communicating R&D results to the field.

Several TICs emphasized the value of internal publicity, including in-house newsletters and telephone hotlines to describe new R&D products from EPRI and to publicize technology transfer success stories. Others stressed the importance of TIC participation in regular meetings of line employees, along with presentations on new R&D products to both upper management and operations managers at power plants. Kansas City Power & Light representatives discussed an added dimension in internal publicity—a newsletter they produce that is devoted specifically to their R&D activities.

Working Together

Comments from the TICs on their companies' relationships with EPRI reflected the diversity of a membership that ranges from rural distribution cooperatives to large utilities using several different generating options. In general, smaller utilities emphasized that EPRI staff can provide technical expertise not always available from their own staffs. Representatives of larger utilities, on the other hand, tended to focus on the communications and organizational problems related to information distribution and staff involvement across their large networks.

In spite of the differences in their organizations, the TICs identified several mechanisms through which all utilities can work with EPRI to enhance technology transfer. Case studies presented at the meeting showed that participation in EPRI's advisory structure can help utilities in two ways: as a forum for R&D planning and as a technology transfer mechanism. "We've identified a strong correlation between high participation

and high benefits from EPRI R&D in areas of strong interest to our company," said Ray Dunlop, director of R&D for New England Electric System. "Participants often increase their interest in R&D and the potential benefits of its application in the field."

A separate panel discussion focused on the technology transfer role of benefits assessments, structured programs in which EPRI staff work closely with utility personnel to quantify the present and future return on the utility's investment. "In addition to the obvious importance of measuring the return on investment, we're building new relationships between utility and EPRI staffs and are discovering new ways to integrate corporate goals and objectives with technology applications just now emerging from the R&D pipeline," said Bill Coleman, EPRI's regional manager for the Northeast.

Informing the Public

The TICs also discussed communication with the public as itself an important form of technology transfer, particularly in the case of sensitive issues, such as possible health effects from exposure to electric and magnetic fields (EMF). One presentation by Jack Rassi, supervisor of the Environmental Projects Division at Salt River Project, detailed its use of EMDEX, an EPRI-developed instrument for measuring EMF, in an imaginative and successful program to inform the public about this volatile issue. "The use of R&D results to inform utility personnel and the public on issues of concern is itself a form of technology transfer," said Larry Critenden, an SRP press representative who worked with Rassi on the program. "The value of R&D results used this way may be difficult to quantify, but it is significant nonetheless."

By the meeting's end, technology transfer had been analyzed as a dynamic process involving both EPRI and its members and consisting of several different mechanisms. Representing all the geographic and technologic diversity of the utility industry, the TICs came away with new information and a range of new perspectives for application to their individual utilities. "The technology transfer process is still maturing," said Rolfe. "The meeting helped many of us to survey what's happening across the industry and to recognize how we can go forward and achieve even more through our relationship with EPRI." ■

Coal Preparation

Advanced Fine-Coal Dewatering

by Clark Harrison, Coal Combustion Systems Division

The electric utility industry burned 685 million tons of coal in 1987. Approximately 15% of this tonnage was water—more than 100 million tons. Assuming an average hauling distance of 400 miles, utilities spent $1.6 billion to transport water, then used more than 200 trillion Btu (equivalent to 10 million tons of bituminous coal) to evaporate it.

EPRI has been investigating means of reducing moisture in coal and coal refuse since 1980, when it supported fine-coal dewatering studies at the University of California at Berkeley. At that time, EPRI also enlisted the help of Dow Chemical to investigate silicone additives for dewatering fine coal. When EPRI's Coal Quality Development Center (CQDC) was dedicated in 1982, a major part of its test plan was to develop and demonstrate promising dewatering processes and equipment. In 1985 the Empire State Electric Energy Research Corp. (Eseerco), already a CQDC cosponsor, dedicated an additional $175,000/yr specifically for dewatering R&D because Eseerco member utilities had continuing problems with coal moisture.

Utility coal suppliers use thermal dryers to reduce moisture in coal. These dryers, however, have several drawbacks.

- They normally require combustion processes, which, in turn, require permits. The procedure for acquiring a permit is as formidable as that for attaining a permit for an electric power plant.
- Costs for the fuel that thermal dryers consume can exceed 50¢/t of dried coal product.
- In many air quality basins, new combustion processes are prohibited.
- Thermal dryers require considerable maintenance. Fires and explosions are common, causing downtime and additional maintenance costs.

The aim of the CQDC dewatering program is to investigate potential alternatives to thermal drying. Since beginning the program, CQDC engineers have demonstrated the effectiveness of several dewatering devices, including a particularly promising pressure filter with a unique air-drying cycle. This filter, manufactured by Larox of Finland, had already proved its capability to dewater minerals but had not yet been tested on coal (Figure 1).

Pressure filters

The pressure filter with an air-drying cycle (PFAC) differs from other plate and frame pressure filters in that it does not use pumping pressure for dewatering. Most pressure filters use a centrifugal pump to fill chambers with slurry until the pressure reaches about 150 psig (1.1 MPa). During this cycle, water is expelled through filter cloth. A piston pump completes dewatering by raising the pressure to about 250 psig (1.8 MPa), forcing out most remaining moisture. A PFAC also uses a centrifugal pump to fill its chambers. However, it uses compressed air against a rubber diaphragm (at 150 psig; 1.1 MPa) to press the solids against a filter cloth and squeeze out any remaining water. Then the filter blows compressed air (at 80 psig; 655 kPa) through the cake in a unique air-drying cycle to complete the dewatering process. CQDC investigators compared the filter's capital and operating costs with those of other dewatering processes, assuming a 1200-t/h cleaning plant that produces both a middling and a premium clean coal, each with 7% total moisture.

This study postulates two cases. In the first case, vibrating centrifuges dewater the +100 mesh and vacuum disk filters de-

ABSTRACT *Dewatering is an important and necessary process in preparing coal for use in power plants. In 1987 utilities spent $1.6 billion to transport water—the unwanted moisture contained in raw coal—and then used up large amounts of energy to remove it or evaporate it in the boiler. Years of research have culminated in a unique pressure filter system with an air-drying cycle. This and other promising processes may save utilities some of the more than 200 trillion Btu used to evaporate the unwanted water from coal.*

water the −100 mesh fraction. Thermal drying achieves a final moisture content for each.

In the second case, vibrating centrifuges dewater the +28 mesh fraction, high-gravity solid-bowl centrifuges dewater the 28 × 100 mesh fraction, and PFAC units dewater the −100 mesh fraction. The pressure filters achieve a final moisture content of 7% without thermal drying.

Economic analysis of these cases reveals that a cleaning plant using PFAC units would save $8 million in capital costs and $5 million in annual O&M costs.

Dewatering tests

The CQDC was the first to test this filter in the United States. CQDC engineers first used the device on Robinson seam subbituminous coal refuse (CS-4081). When the filter achieved moistures as low as 6% during setup tests, CQDC engineers recognized the potential for using the device on clean coal, which is much easier to dewater than is refuse.

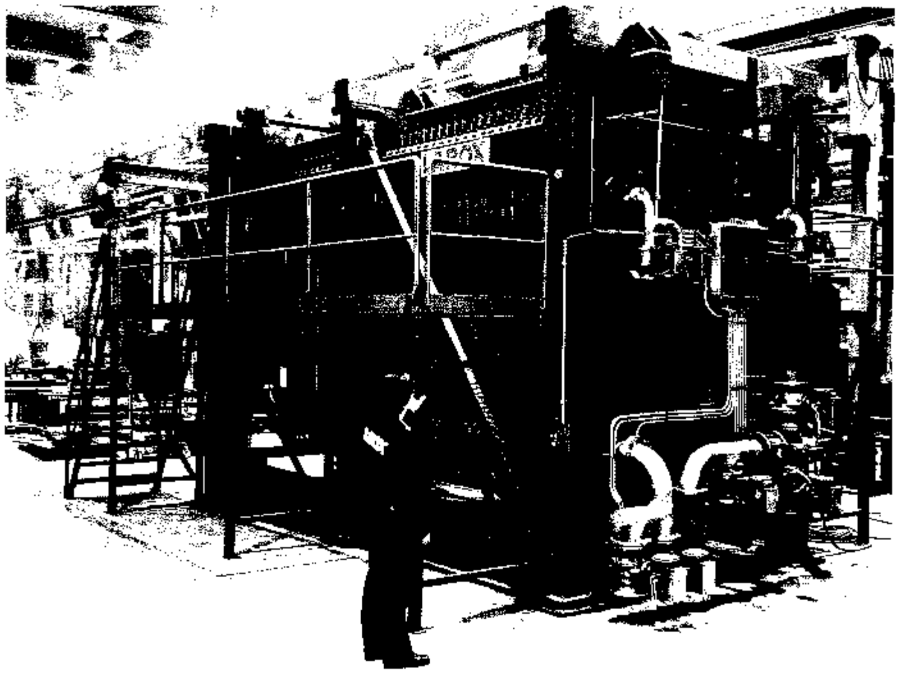
In 1985 CQDC engineers tested the pressure filter on Upper Freeport seam clean coal from western Pennsylvania. This particular work, described in CS-5869, had the following test objectives.

- Demonstrate this filter over a wide range of operating conditions
- Develop a model for predicting the PFAC unit's capacity and achievable moisture reduction for coals similar to the test coal
- Determine the economics of using PFAC in place of thermal drying

The Upper Freeport coal arrived raw at the CQDC and was crushed to ¼ in top size. CQDC froth flotation units cleaned the −28 mesh and −100 mesh fractions, which researchers saved in an agitated storage tank for the dewatering tests.

The higher pressure (150–250 psig; 1.1–1.8 MPa) used in pressure filters makes them more effective for dewatering fine fractions than other dewatering units, such as basket centrifuges and vacuum filters. Fine coal is lost through centrifuge baskets, and vacuum filters are limited to one atmosphere of pressure (14.5 psi). To determine the most economic application for the filter, CQDC engineers divided PFAC dewatering tests into two series: (1) a split circuit in which the PFAC unit dewatered the very fine −100 mesh fraction and a high-gravity centrifuge that dewatered the larger 28 × 100 mesh fraction, and (2) a single circuit in which the PFAC unit dewatered the entire −28 mesh fraction.

Figure 1 **Research at EPRI's Coal Quality Development Center shows that the pressure filter with air-drying cycle can eliminate thermal drying. The filter shown here is manufactured by Larox of Finland.**



The research team ran 29 tests for each series. The split dewatering tests provided data for evaluating the PFAC unit's capability to dewater very fine material. Both series supplied data for developing a predictive model to project filter performance and for comparing PFAC economics with those of thermal drying.

Test results

These tests on Upper Freeport seam clean coal produced cake with less than 12% surface moisture for the −100 mesh feed and less than 10% for the −28 mesh feed, compared with conventional processes, which would leave about 18% moisture in the coal. These results demonstrate that this unique pressure filter is an economical alternative to thermal drying. CQDC engineers used data from both test series to develop predictive models applicable to the two different feed sizes. Data from both series were then pooled with the results from dewatering tests that had used the PFAC on Sewickley seam coal in order to develop a more general model applicable to a wider variety of coals. These models are suitable for the preliminary design of a coal-cleaning, plant-dewatering circuit. They can also reduce the amount of testing necessary for final design.

The PFAC is available in commercial sizes up to 40 t/h for a single unit. Utilities and coal companies using this pressure filter can reduce coal costs by $1.50/t, or 5¢/MBtu.

Other promising processes

CQDC engineers are also investigating other interesting dewatering processes. For one example, a high-gravity, solid-bowl centrifuge is being tested on −28 mesh clean coal to see if it can achieve moistures comparable to conventional screen-bowl centrifuges but at high solids recovery. This centrifuge uses forces up to 3000 times gravity. CQDC tests in 1985 on 28 × 100 mesh clean coal demonstrated that this centrifuge can achieve 8% surface moisture at a 99.5% solids recovery.

For another example, a belt filter press—traditionally applied to coal refuse—is being tested on clean coal to see if it can economically produce lower moisture than the traditional vacuum disk filter for the −100 mesh fraction. The belt filter press uses polymers to combine fine particles, then squeezes the flocs between two filter belts to expel water.

For testing in 1989 and 1990, CQDC engineers are also evaluating ultrasonic dewatering and a high-speed centrifugal dryer, which combines the best features of a centrifuge and a filter.

A list of EPRI reports that more fully describe CQDC dewatering test results can be obtained from the project manager.

Reactor Vessel Integrity

Pressure-Temperature Limits for Pressure Vessels

by Timothy Griesbach, Nuclear Power Division

ABSTRACT *One of the main concerns in nuclear plant operation is protecting the vessel against brittle fracture. The ASME Code and the Code of Federal Regulations prescribe plant operating pressure-temperature limits, including safety margins for normal operation. These limits must be updated periodically to reflect the condition of the steel vessel wall after many years of neutron irradiation. In older plants, this may impose some operational restrictions. The results of EPRI's research should provide guidelines for safe, continued operation of vessels well into the twenty-first century.*

A nuclear pressure vessel must withstand pressures as high as 2250 psi (15 MPa) and temperatures of 550°F (288°C) during normal operation. The walls of a pressurized water reactor vessel are made of steel sections up to 10 in (25 cm) thick to keep the levels of pressure-induced stress acceptably low. Thermally induced stresses must also be accounted for in the vessel design. These thermal stresses develop whenever the plant goes through temperature variations, such as during a normal heatup or cooldown.

A vessel's ability to withstand all these stresses must be considered in the vessel design and in the choice of material. For example, a vessel's integrity could be challenged if a flaw is present in a region where the combination of stresses is high enough and material toughness low enough to cause an existing crack to grow deeper into the wall. The rapid propagation of a preexisting crack is known as a brittle fracture. Vessel steels are chosen for their resistance to brittle fracture, although radiation effects can change the material properties and reduce the resistance capability (fracture toughness) in steels.

To protect the vessel against brittle fracture in the presence of a flaw, plant engineers must accurately consider the vessel design characteristics and current material condition when establishing criteria for normal operation. An NRC licensing review of the pressure-temperature operating limits is performed periodically for each plant to ensure compliance with the Code of Federal Regulations and the ASME Code. These regulations use the principles of fracture mechanics, with specified safety margins, to monitor the vessel material toughness and to ensure against brittle fracture of the vessel.

Surveillance monitoring programs are required in all plants to measure the actual changes in vessel toughness. The surveillance data are then used to update the plant operating pressure-temperature limits. These data have also been used to develop trend curve prediction methods for radiation damage in vessel steels, such as those given in NRC Regulatory Guide 1.99. The recent issuance of Revision 2 to this guide will require plant pressure-temperature limits to be updated by using new criteria, which will impose additional restrictions on the operating pressure-temperature limits for some plants. Although these pressure-temperature limits are an important element in maintaining plant safety, it is also important that utilities not be overly conservative in determining plant operating criteria that could unnecessarily limit the useful life of reactor vessels.

For more than 10 years, EPRI research has addressed the vital issue of reactor vessel integrity. Much of EPRI's work has been devoted to quantifying the effects of neutron irradiation on the toughness of reactor vessel steels. Other EPRI studies have developed the technology of elastic-plastic fracture analysis methods to more accurately predict a vessel's inherent resistance to failure. EPRI's contribution in compiling a reactor vessel material data base has been instrumental in eliminating conservatism for many plants that were lacking material chemistry data and thus were forced to use worst-case assumptions in predicting vessel embrittlement. The economic benefit to these plants in reduced regulatory restrictions is significant. Results of these studies may also justify extended vessel life.

Effects of irradiation

Reactor vessels are fabricated from very tough ductile steel plates or ring forgings. These large segments are welded together to form the final structure (Figure 1). The cylindrical walls of the vessel contain the reactor core and are exposed to a continual stream of neutron irradiation from the nuclear reaction. These high-energy atomic particles pass through the thick steel walls, but in doing so, may collide with atoms in the metal and knock them out of position. The accumulation of these atomic defects eventually causes a stronger steel, but one that is less resistant to fracture if flaws are present. In the late 1960s vessel welds containing small amounts of copper were discovered to have become damaged at a faster rate than the surrounding base material. Copper in the vessel welds made after 1972 was substantially reduced, but in a number of older vessels these copper-bearing welds remained. Because the amount of damage appeared to be related to both copper levels and neutron fluence exposure, it became important to accurately predict the cumulative effects of irradiation on embrittlement.

EPRI studies were conducted to investigate the microscopic effects of neutron exposure and thus more clearly understand the mechanisms of damage to the vessel materials. The results of these studies gave the industry a mechanistic model that hypothesized the formation of small copper precipitates, or clusters, under long-term neutron exposure. The formation of these fine copper clusters would cause a measurable loss of toughness in the metal as observed in the plant material surveillance tests. By statistically fitting the plant surveillance data to the mechanistic model, researchers developed an improved prediction method.

An interesting feature of this model soon became apparent. If the damage to the vessel welds was caused primarily by copper precipitates, this mechanism of damage would saturate and diminish as all the available copper atoms were used up during cluster formation. As a consequence, the initial high rate of embrittlement would significantly decrease at increased levels of fluence. Indeed, this theory was confirmed by the data and indicated a lower projected end-of-life embrittlement level for the vessels with copper-containing welds.

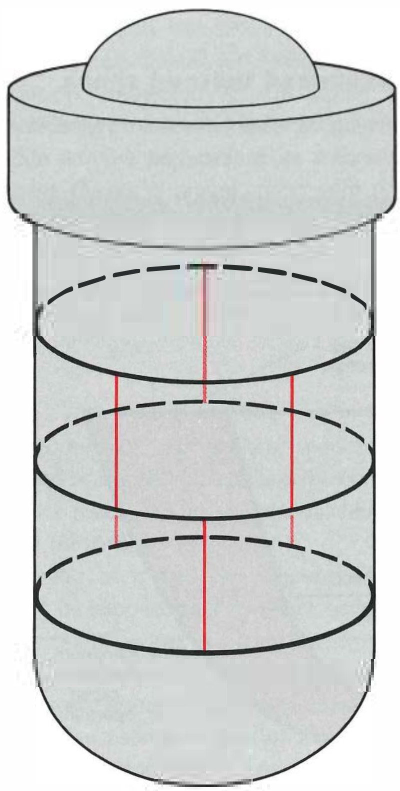


Figure 1 A reactor pressure vessel is typically made from welded plates or forgings. Both longitudinal (color) and circumferential (heavy black) welds may exist in the beltline region of the vessel. The irradiated properties of the weld and plate materials must be considered when establishing operating limits.

Later findings indicated that nickel also contributed to the embrittlement rate. The damage prediction models were further refined to account for the complicated combined effect of copper, nickel, and fluence on vessel toughness properties.

The EPRI studies helped remove uncertainties in the prediction methods that form the basis for Regulatory Guide 1.99, Rev. 2. For some plants this has resulted in a benefit: a reduced level of predicted damage in the vessel wall. Other plants may see an increase in the calculated level of embrittlement that must be accounted for in the plant operating criteria.

Pressure-temperature limit curves

Normal plant operating criteria are defined in the technical specifications for each plant in terms of allowable pressure-temperature limits. These limits contain many safety factors to maintain an adequate margin against brittle fracture of the reactor vessel. The margins used in establishing these limits are given in Section III of the ASME Code. Plant operators are required to adhere to these pressure-temperature limits during normal plant heatup, cooldown, and hydrostatic and leak testing.

The effects of irradiation on changes in the vessel toughness properties must be accounted for in calculating the allowable pressure-temperature limits. Typically, these operating limit curves are updated every 5–10 years to reflect the changing condition of the vessel's steel walls. The increased radiation damage results in a shift in the pressure-temperature curve, which reduces the maximum pressure permitted at any given temperature (Figure 2). A constant lower limit of pressure exists to prevent cavitation and damage to pump impellers. Thus, the window for operation between these two limits closes as plants continue to age.

Recognizing the potential problem for operating plants, EPRI initiated a project to evaluate reactor vessel integrity in the event that these operating pressure-temperature limits are inadvertently exceeded (RP1757-41). Following any violation of the pressure-temperature limits, the plant technical specifications require the plant owner to shut down and evaluate the reactor vessel's structural integrity. Until recently, however, the ASME Boiler and Pressure Vessel Code did not provide procedures or criteria to perform such an evaluation. With EPRI support, simplified guidelines were developed to evaluate reactor vessel integrity following out-of-limit operation. These guidelines were accepted into the Code in 1986 as part of Section XI, IWB-3700. In most cases, a simple posttransient evaluation will quickly demonstrate that a reactor vessel is ready to return to normal operation. Because NRC has endorsed these ASME Code guidelines, evaluations of a vessel on the basis of the guidelines may be accepted quickly, eliminating days or weeks of costly analysis and plant downtime.

Southern California Edison experience

During a routine refueling outage in 1986, Southern California Edison's San Onofre Unit 2 experienced an overheating event that exceeded the specified technical specification limits. The utility hoped to avoid prolonging the outage by an analysis to confirm that the vessel was safe for plant restart. As it turned out, an Edison engineer, Steve Gosselin, was able to evaluate Unit 2 vessel integrity immediately. "With the help of these new guidelines, recently accepted by ASME and endorsed by NRC, we were able to return to power quickly and safely after the incident."

Pressurized thermal shock

A limiting condition on reactor vessel integrity known as pressurized thermal shock (PTS) may occur during a severe system transient. Such a transient could challenge the integrity of a pressurized water reactor vessel under the following conditions.

- Severe overcooling of the inside surface of the vessel wall followed by high repressurization
- Significant degradation of vessel material toughness caused by radiation embrittlement
- Presence of a critical-size defect in the vessel wall

During the early 1980s EPRI, NRC, and plant vendors conducted extensive research on the PTS issue. In 1985 NRC issued a formal ruling on pressurized thermal shock, which limits the amount of embrittlement in PWR vessels as measured by the nil-ductility reference temperature (RT_{NDT}). The ASME Code established RT_{NDT} as a temperature index to reference the vessel material fracture toughness.

The NRC limits on RT_{NDT} as defined in the PTS rule were intended as screening criteria for plant operation and were established by using conservative analysis techniques. All PWR vessels in the United States have been required to evaluate vessel embrittlement in accordance with the criteria, with projections through end-of-plant life. EPRI studies confirmed that the possibility of vessel rupture from a severe pressurized thermal shock transient does not pose a problem for plants operating within the allowable limits because sufficient margin against vessel fracture exists even beyond these limits. Although all operators are striving to keep plants below the screening criteria limits, plans for life extension of a number of vessels could be affected if the NRC criteria are strictly enforced.

In response to continuing industry concerns on the issue, EPRI has looked carefully at the conservatisms in evaluation of material degradation and the analysis procedures used in evaluation of a PTS event. As a consequence, EPRI sponsored a testing program to examine the behavior of a precracked specimen of vessel steel under conditions similar to PTS (RP2180). The work was performed by Combustion Engineering under the direction of Douglas Norris, head of EPRI's Structural Mechanics group.

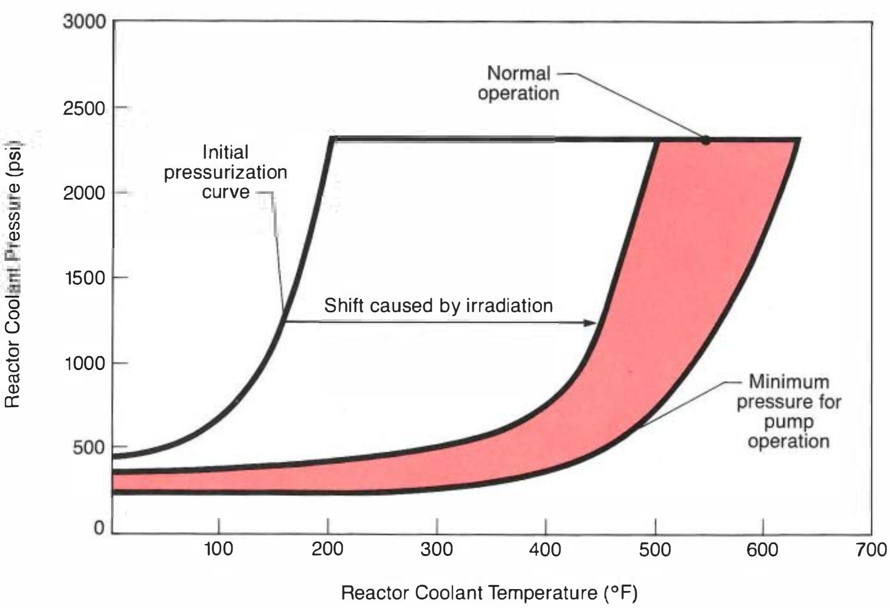


Figure 2 The pressure-temperature limit curves for each plant must be revised to reflect the current condition of the vessel, including the effects of irradiation embrittlement. This may cause a narrowing of the window for operation (color) during plant heatup and cooldown.

The behavior of the critical-size flaw in a vessel was examined under extreme thermal loading conditions. EPRI discovered that substantial margins exist against vessel failure that were not used when NRC developed its current PTS rule. "These tests demonstrate that an initiated crack will arrest with less penetration of the vessel wall than was calculated by previous analyses used to determine the [NRC] screening criteria," says Norris. "Further, our tests show that arrested cracks have more trouble reinitiating than existing models would predict. Although the NRC criteria were chosen to be extremely conservative, the conclusion from these EPRI studies indicates that there is even less potential for complete vessel rupture than was previously predicted."

Management of vessel embrittlement

For the aging fleet of nuclear power plants in the United States, questions about managing vessel embrittlement continue to emerge. Are the levels of damage to the steel walls of the vessels within safe limits? Should the older vessels be allowed to continue operation, and if so, for how long? For utilities planning extended plant life, these questions take on added importance. Will the vessel be the limiting component for plant life? Can an embrittlement management program be initiated to mitigate the effects of radiation damage and extend plant life?

There are still many unanswered questions about the long-term effects of embrittlement. However, because of the long lead time and high cost required to replace a large nuclear generating facility, the answers to these questions take on great significance. Utility executives are faced with the difficult task of making decisions today that will affect the reliability and availability of reactor vessels for the future.

To assist in the process of planning for extended vessel life, EPRI is coordinating the Resource Center for Pressure Vessel Reliability dedicated to developing the technology for ensured safe plant operation. This resource center combines EPRI expertise in materials, structural mechanics, in-service inspection, corrosion control, and other specialty areas.

A major part of that effort is a new three-year research program within the Structural Mechanics group on management of reactor vessel irradiation embrittlement (RP2975). The objective of this research is to develop an industrywide methodology to resolve those vessel embrittlement issues that may unnecessarily limit the useful life of light water reactors. Its result will be a set of utility options and guidelines for remedial measures to manage the long-term effects of embrittlement. Because these issues are generic in nature, a collaborative effort involving EPRI, the nuclear steam supply system vendors, and lead-plant utilities to develop a unified industry approach is under way. By providing utilities with the necessary data and technology to minimize the effects of irradiation damage, such an approach can ensure vessel availability for many years to come.

Air Quality

Plume Model Development

by Gordon A. Beals, Environment Division

For 50 years plume models have been providing general guidance for power plant design, such as the rule of thumb that maximum ground level concentrations of stack effluents are related inversely to the square of the effective stack height. Advances in understanding the turbulent motions of the lower atmosphere have enabled meteorologists to calculate fairly well the maximum concentrations that may occur somewhere in the general vicinity of a power plant (at least in moderately flat terrain). However, EPRI's plume model validation and development (PMV&D) experiments conducted at Commonwealth Edison's Kincaid power plant and Tennessee Valley Authority's Bull Run power plant have shown that currently available plume models lack desired precision in predicting the concentrations measured at specific places and times (RP1616).

Instead of a specific concentration, a newly developed plume model estimates the probability that a concentration measured at a particular place and time will exceed some specified threshold value. Such probability estimates are fundamental inputs to risk assessment models and many modern economic decision-making tools.

The need for a probability model is rooted in the inherently turbulent nature of the atmosphere. Even indoors the smoke rising from a cigarette undulates in an irregular pattern in response to weak turbulent eddies. Outdoors, the size and intensity of the irregular motions are much greater, making it impossible to know precisely the plume motion and plume spread without constantly measuring every detail of atmospheric motion at an infinite number of points. The best scientists can do is to measure the atmospheric motion at a few places and develop some rules about the average behavior of the plume-dispersing eddies.

The new plume model is the outgrowth of research begun five years ago under EPRI sponsorship at the Aeronautical Research Associates of Princeton (ARAP), now the ARAP Division of California Research & Technology (RP1616-28). ARAP's responsibility was to develop a three-dimensional

ABSTRACT *Plume models are routinely used in power plant design analyses to predict ground level dispersion of plant stack effluents. But studies show that predictions made with the currently available models are not sufficiently accurate in predicting stack effluent concentrations at specific places and times. Instead of predicting concentrations, a new plume model estimates the probability that a given measured concentration will exceed a specified threshold value at a certain time and place, thus providing fundamental input for other risk assessment models.*

time-dependent model of the movement and dispersion of plumes from utility stacks. In approaching the task, ARAP scientists decided they had to develop a framework in which treatment of the contribution of turbulent wind fluctuations to the uncertainty in time-averaged concentration values is consistent with the treatment of the contribution of the turbulence to the diffusion of the mean plume concentration.

These attempts to parameterize the variance (mean square deviation) of the instantaneous concentration from its theoretical long-term mean in terms of the same turbulence variables that control the diffusion of the mean plume concentration were successful. Also related to these turbulence variables is a time scale of the fluctuation of concentration, which, with the sampling duration, determines the uncertainty—that is, the average deviation between mean values (theoretically obtainable for infinitely long sampling) and values for a specific sampling time (e.g., 1-hour average). The time scale depends initially on the stack diameter and internal plume turbulence but adjusts rapidly to the time scale imposed by the turbulence of the surrounding atmosphere.

To calculate the uncertainty in the plume concentration for a specific location, the model calculates the plume travel time to that location, the time scale, and the magnitude of the fluctuations in concentration. The magnitude, together with the measuring time (e.g., 1-hour average) and the time scale, can then be used to estimate the uncertainty. This uncertainty is then used with the predicted long-term mean concentration to parameterize the probability distribution of possible concentrations for a specific location.

The probability distribution needed for risk assessment at a point can be obtained by running through the model many different hours of data with actual values of meteorologic inputs and turbulence levels, drawing a number of predicted values from each hour's concentration probability distribution. The resulting overall cumulative concentration distribution would look like the one shown in Figure 1. This figure compares the model's predicted concentration distribution for ARAP's lowest resolution, most economical member of the new model family with the distribution of actual measurements from the Kincaid PMV&D experiment. With enough resampling of each hour, it is possible to generate confidence limits on this distribution (also indicated in Figure 1). The figure was generated by aggregating the results for approximately 18,000 sampler-hours during the intensive measurement periods in the Kincaid PMV&D project. However, a similar cumulative frequency diagram, including confidence limits, can be made for a single point and the 8760 hours in a year or for some other number of hours.

The probability distribution developed in this way is just one of several that may have

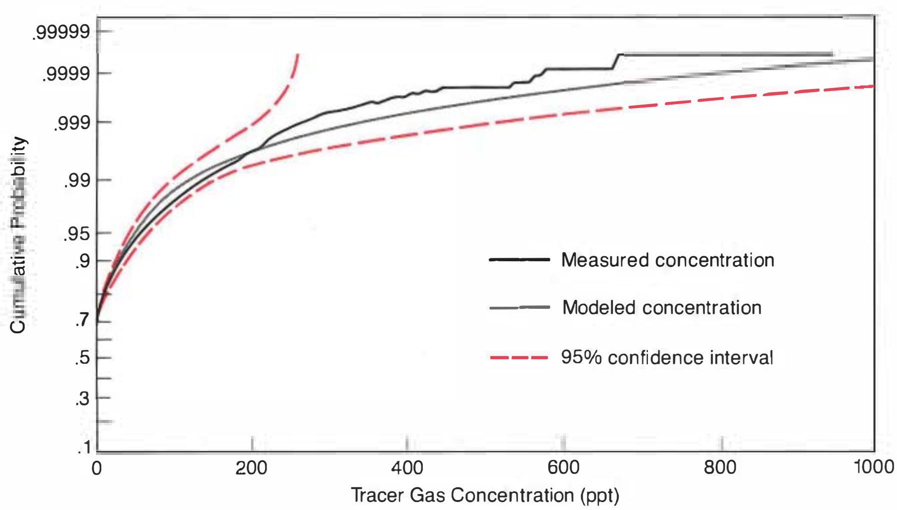


Figure 1 Cumulative probability distribution of measured and modeled tracer gas (SF_6) sampler concentrations for the Kincaid model development data. The curves show the measured and predicted probabilities that the tracer gas concentration will be less than the specified concentration value. In addition, the 95% confidence level is shown.

to be merged to provide an overall estimate of the risk of human exposure to, for example, sulfur dioxide. Other variables might be the distribution of sulfur in the power plant coal supply, the distribution of people in the vicinity of a power plant, and the distribution of indoor or outdoor activities. Each of these would have its special distribution function, but once the distributions have been defined, they can be combined to obtain an overall measure of risk.

Such studies have been hampered in the past by an inability to place confidence limits on the plume dispersion component of the risk assessment. So this new plume model family is a major step forward in assessing risks and providing information for air quality regulation.

Demand-Side Management

Modifying Electricity Usage Patterns

by William M. Smith, Energy Management and Utilization Division

Utilities use demand-side management (DSM) to directly influence customer demand for electricity in predetermined ways. This influence affects load shapes (the time-varying use of electricity) by increasing or decreasing the use of electricity or by simply shifting use from one time period to another (Figure 1). Alternative load shape objectives such as strategic load growth or conservation can be selected to meet the needs of a particular utility.

EPRI's DSM research efforts have developed an operational procedure to help utilities plan, evaluate, implement, and monitor DSM programs (RP2381-4; 2548-1). The project team examined current information about DSM and integrated it into new research on specific DSM program planning and implementation. As a result, information about project planning, specific project data, and customer and utility experiences have been incorporated into a series of general information guides, specific topic reports, and computer software dealing with demand-side planning.

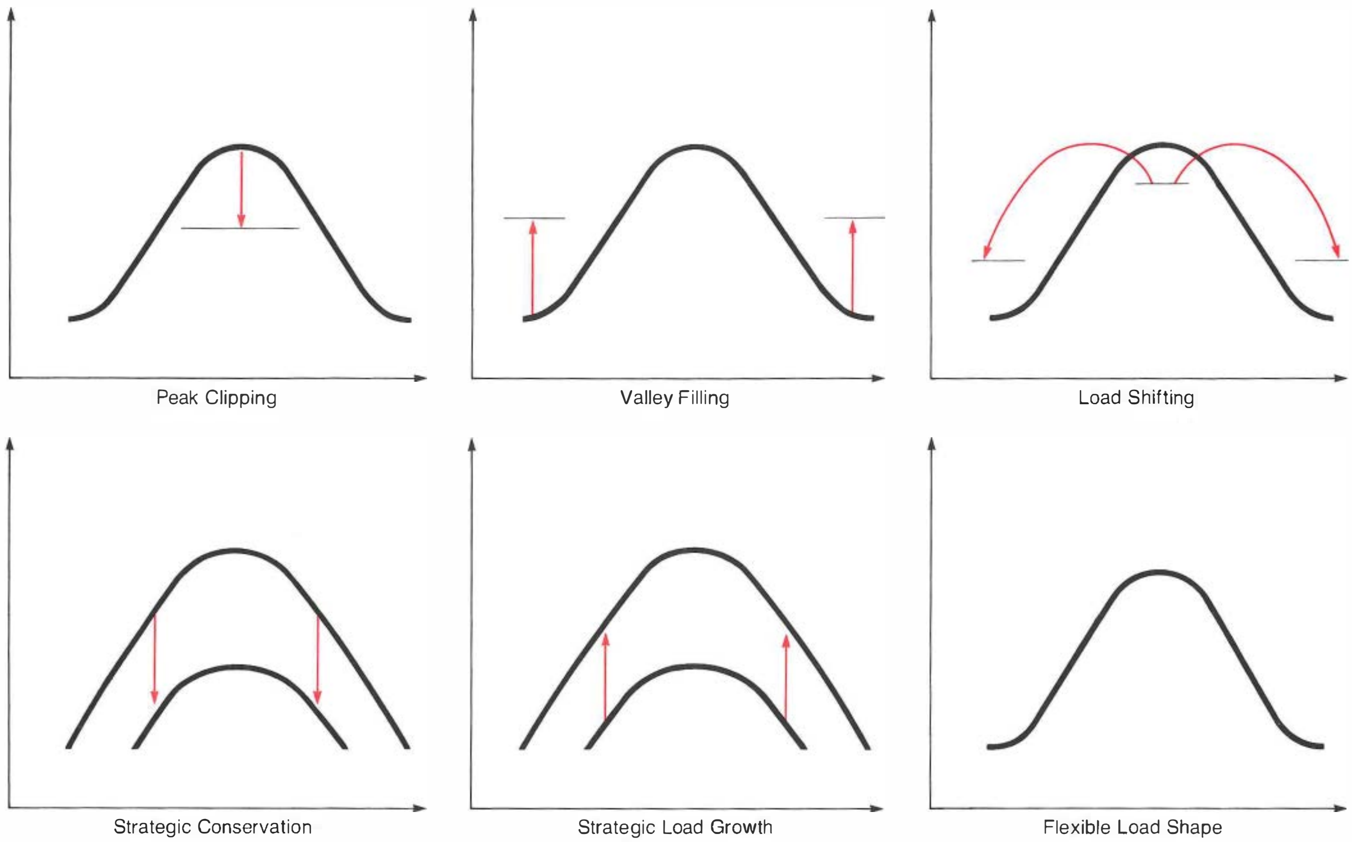
A primary objective of the DSM research projects is to encourage utilities to recognize that demand-side planning and supply-side planning are equally important and practical. Early in DSM's history, utilities often introduced a single DSM alternative into their supply-side planning processes without considering its broader implications. Although this procedure often allowed utilities to test the feasibility of a specific DSM alternative, it did not allow comprehensive testing of DSM as a separate planning option.

As the benefits of individual DSM alternatives materialized (primarily their flexibility and customer-oriented focus), the importance of incorporating DSM planning into a utility's overall strategic planning process became clearer. Generally, DSM activities can be designed and implemented in a much shorter time than can supply-side alternatives. This flexibility allows planners to adjust or even dismantle specific DSM alternatives (such as strategic conservation and load management programs, as well as electrification, technology enhancement, and varying levels of customer service) if substantial changes in a utility's operating environment occur. Effective DSM program planning also requires that utilities develop programs that allow customers to manage their total energy use and costs more effectively, while at the same time meeting a utility's desired load-shape changes.

To provide a level of demand-side planning information comparable to that found in supply-side planning, the DSM project was structured to examine each step of a traditional planning process and to tailor it specifically for DSM planning. The information gathered for each step, or topic, would then provide a documented guide for utility planners (Figure 2). The DSM planning and decision-making process consists of nine topic areas: (1) objectives, (2) alternatives,

ABSTRACT *Utilities can modify load shapes through demand-side management (DSM) programs, but the programs must be carefully designed and effectively implemented. In its DSM research projects, EPRI developed procedures and topical resource materials that utilities can use to systematize DSM program development. Planning, evaluating, implementing, and monitoring DSM programs by using the project's guidelines will help ensure that both the utilities and their customers benefit from DSM changes.*

Figure 1 Managing the demand side of the utility-customer relationship to alter the load shape. Load shapes, which reflect the time-varying use of electricity, can be effectively modified by DSM techniques that increase or decrease electricity use or that shift load segments from one period of the day to another.



(3) customer acceptance, (4) customer response, (5) load-shape impacts, (6) other impacts, (7) evaluation, (8) program implementation, and (9) program monitoring.

Each of these nine topics was treated as a separate research subject, and resource products (reports, handbooks) were produced for each. Topics 1–7 cover program selection, and topics 8 and 9 cover program implementation and monitoring. Computer software was produced for appropriate topics (customer response and evaluation). Findings from the projects (RP2381-4, RP2548-1) will be summarized in a series of primers and an overall guidebook.

The program selection topics (topics 1–7) affect utility strategic planning processes, including utility goals, customer concerns, technology alternatives, regulatory requirements, and cost-benefit issues. Each of these topics is discussed below.

Topic 1, objectives, is concerned with the objective development and prioritization steps in a strategic planning process. It focuses on how utilities can effectively establish DSM objectives and then translate those objectives into operational programs. This topic considers the variety of factors that may affect DSM objective planning, provides an overview of the barriers that may exist in setting DSM objectives, and spells out the necessary analytic requirements. Practical utility case study examples are provided in the topic report.

Topic 2, alternatives, covers information utilities can use in assessing DSM's usefulness in meeting their needs, as well as those of the customer. Two sets of matrixes (overview and functional) were developed that allow utility planners to conduct inter-technology comparisons. The overview matrixes illustrate the relationships between the various DSM components, including technology alternatives, end uses, load-shape modification objectives, market implementation methods, and customer types. Thus they provide an initial matching of customer types and technology alternatives for future examination. The functional matrixes, organized by technology alternative, help a planner match these specific alternatives with load-shape modification objectives, end uses, and appropriate market implementation mechanisms.

Unlike their relationship to supply-side activities, customers elect to participate in DSM projects. Topic 3, customer acceptance, addresses the qualitative aspects of DSM program marketing. It provides insights and guidance for designing DSM programs that customers will accept, and it draws heavily on a variety of market research information sources, including a survey of over 100 utilities regarding their experiences with customer acceptance of DSM programs. Focusing on program promotion techniques and participation rates, this research found that formulas for success suggest that customer-specific information must be accurate, that customer and utility needs must be met effectively, and that information about each DSM project must be communicated properly to the correct audiences.

In topic 4, customer response, sources of load-shape data and current and new methods for assessing the load-shape data are reviewed, and current and new methods for assessing the load-shape impacts (i.e., customer response) of various DSM options are discussed. Various data bases, software, and guidelines for evaluating customer response that were developed specifically for this project are presented. Four principal elements are used to assess customer response: reference load-shape data, adjustments for developing service-area-specific load shapes, reconciliation with known demand and energy use characteristics, and load-impact analysis.

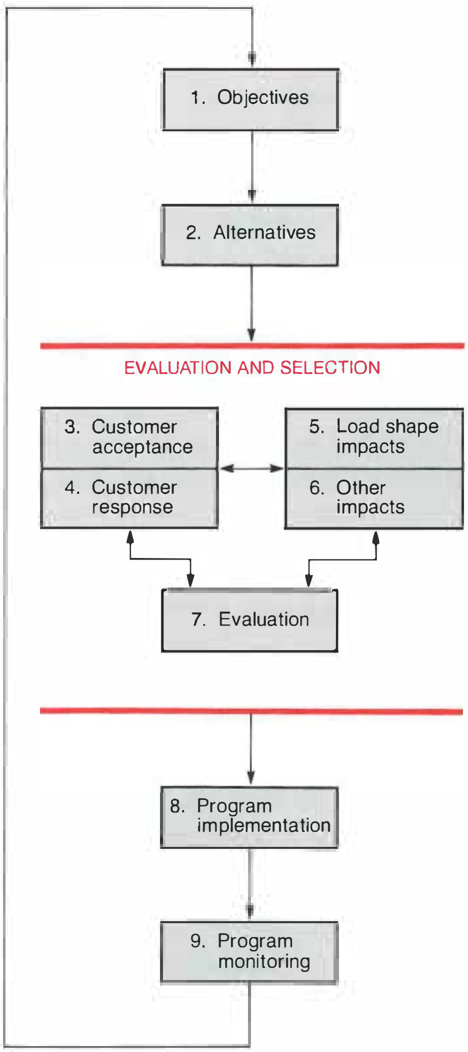


Figure 2 Research topics in the demand-side management research projects. As shown, the DSM planning and decision-making process consists of nine topic areas.

Topic 5, load-shape impacts, covers the effects of various DSM programs at the system level, both individually and jointly. Certain DSM programs (thermal energy storage and time-of-use rates) can complement each other to induce greater market penetration; others, such as instituting a time-of-use rate for existing direct load control customers, can conflict. The net effects of these latter activities must be evaluated carefully to avoid double counting.

Topic 6, other impacts, separately covers regulatory as well as transmission and distribution (T&D) issues. Planners at regulated utilities must consider how regulators will respond to the addition of DSM programs to their companies' operations. Issues addressed include the current regulatory environment, the sometimes differing perspectives of regulators and utilities, and trends in regulatory policies. A survey of regulatory commissions and a case study of the Florida regulatory situation contributed to the findings in this topic area.

When conducting DSM program planning, utilities must also consider that whereas DSM may provide generation savings, it may also result in the need for transmission or distribution facility upgrades. As a result, utilities must explore the impacts that various DSM activities may have on T&D issues and examine opportunities for achieving generation savings without incurring additional T&D capital costs.

Topic 7, evaluation, precedes program implementation. Before a DSM program can be considered for implementation, utilities must identify and evaluate the costs and benefits of the various DSM options available to them. The DSM evaluation topic focuses on first-level analysis as an initial approach to cost-benefit analysis. It defines and discusses screening, describes a process for ranking multiple DSM alternatives, and briefly summarizes other current EPRI research on evaluation (e.g., End-Use TAG).

Topics 8 and 9, program implementation and monitoring, focus on experiences utilities have had when trying to implement and monitor DSM programs. The implementation topic examines organizational issues, procedures, staffing, and the marketing and provision of DSM program services. It attempts to identify factors from each of these categories that contributed to the success (or failure) of previous DSM programs.

The monitoring work (topic 9), examines the performance and results of a DSM program from several perspectives. Topic 9 presents a variety of useful monitoring methods and techniques, suggests ways to implement monitoring activities, discusses factors that may influence a utility's choice of monitoring techniques, outlines utility-specific monitoring components, and examines three utility and one nonutility monitoring case studies.

Six software models were developed for the customer response and evaluation topic areas (topics 4 and 7, respectively). The purpose of these computer models is to provide help in studies of customer response to DSM programs and in determining how specific DSM technologies satisfy load-shape objectives and how implementation methods enhance DSM technology and program acceptance.

Five of these models make it possible for planners (1) to extract, adjust, and view residential, commercial, and industrial customer load-shape data (RELOAD); (2) to facilitate the incorporation of previously gathered information into combined engineering and statistical models that estimate end-use load shapes from whole-building load research data (PIES); (3) to study customer response to time-of-use rates (RETOU, CIRTOU); and (4) to estimate residential customer response to on-peak demand charges (RODEC).

The sixth model helps with DSM program evaluation. It uses selection matrixes to relate DSM technologies and implementation methods, thus allowing individual users to determine the actual matrix content. It also expands its evaluation scope by more specifically examining the benefits accruing to customers from DSM technologies and from utility DSM programs.

DSM primers and an overall guidebook will provide materials that summarize the broad range of information covered in the nine topic areas. Seven DSM primers, primarily for use by utility executives and their staffs, will contain a condensed summary of DSM planning and evaluation procedures, relevant technologies and programs, and the markets for DSM.

A DSM guidebook, providing a central source for summary information about each of the nine DSM topics, will be published later this year. Those requiring more-detailed information should consult topic area findings. Whichever level of information utility planners need—general or particular—research results from DSM projects offer a valuable guide for planning DSM programs that benefit both utilities and their customers.

A list of DSM project reports, handbooks, and computer software is available from the project manager's office.

Acid Deposition

Lake Acidification Mitigation

by Donald Porcella, Environment Division

ABSTRACT *Adding limestone to acidic lakes is a practical and effective means of raising water pH to levels favorable to fish and other aquatic organisms. Experimental liming of three bodies of acidic water shows the effects of liming to be entirely beneficial. Methods developed in EPRI's lake acidification mitigation project (LAMP) for determining how much limestone to add, predicting the effective period of a liming, and predicting chemical changes in treated lakes are now sufficiently developed for operational-scale liming programs.*

Several means are commonly used to control the quality of lake water. Substances can be added to or removed from inflowing tributaries, or the water can be treated throughout its depth in the lake. Similarly, acidic conditions in lakes and streams can be reversed by controlling the input of acidic substances or by neutralizing the acid in the aquatic ecosystem.

Results from EPRI's lake acidification mitigation project (LAMP) show that acidic lake waters can be effectively neutralized by liming (i.e., by adding limestone). Liming can restore fisheries in fishless acidic lakes, as well as maintain existing fisheries in lakes in which the acidity is increasing (*EPRI Journal*, April/May 1986, p. 15).

A number of chemicals that react with hydrogen ions to neutralize acidity (raise the pH) can be used as liming agents, but limestone is the most commonly used. Commercial limestone can be a mixture of several minerals ranging from pure calcite ($CaCO_3$) to pure dolomite ($CaMg[CO_3]_2$). Because dolomite dissolves more slowly, calcitic limestones have been used in most surface water liming operations. Usually, the calcite is added as a very fine powder (generally less than 2 μm) in dry form or as a slurry.

Limestone has several advantages over other bases like hydrated lime ($Ca[OH]_2$) or soda ash ($NaCO_3$). It neutralizes acidity without causing excessively high or rapidly changing pH; provides acid neutralizing capacity (ANC) to buffer future acidity; and increases the amount of divalent cations, which are physiologically important to fish and may competitively inhibit uptake of toxic metal ions. In addition, limestone is inexpensive, is readily available, and generally contains few toxics or other contaminants.

Despite the apparent harmlessness of liming, several questions concern LAMP investigators.

- Are there long-term ecologic effects from liming?
- Are there short-term deleterious effects on fish or other organisms?
- Will the communities of organisms in limed lakes differ from those in similar lakes with near-neutral pH (i.e., pH near 7)?

▫ Will repeated liming induce sudden increases in trace metals, such as toxic inorganic monomeric aluminum? (Dissolution of $Al[OH]_3$ flocs by acid could kill fish.)

▫ Will liming protect against the periodic acidic inflows that occur after snows melt or after storms?

▫ Will periodic exposure to acidic inflows be more dangerous to certain species or some particular life stage?

Other questions concern the most cost-effective ways of liming, the intervals at which liming must be repeated, and ways to increase the interval between limings.

Experimental limings

LAMP was funded to answer those questions through intensive hydrologic, chemical, and biologic study of three clear-water drainage lakes in the Adirondack Mountains (New York): Cranberry Pond, Woods Lake, and Little Simon Pond (Table 1). The Empire State Electric Energy Research Corp. provides cofunding of the project, and Living Lakes, Inc., a nonprofit organization funded by utilities and others for operational liming, performed the 1986 and subsequent limings.

LAMP began in late 1983, with field investigations beginning in 1984 for Cranberry Pond and Woods Lake and in 1985 for Little Simon Pond. Since then the team of investigators has evaluated the ecologic effects of liming, different liming techniques, the effects of different lake conditions on the success of liming, and how precisely the time when liming should be repeated can be predicted.

Lakes are usually treated with enough limestone to last as long as practical. The amount of limestone needed to neutralize the water throughout its depth (the water column) and the sediment at the bottom is primarily a function of lake volume. The duration of treatment depends primarily on hydraulic residence time (the average time water remains in a lake before being flushed out by inflowing water). Sediment neutralization is equivalent to the exchangeable hydrogen ions in the top layers of the lake sediments. More limestone is added than is necessary to neutralize the water and sediment, thus allowing some to settle to the lake bottom, where it dissolves more slowly and thereby extends the effective duration of the treatment.

Table 1
WATERS TREATED WITH LIMESTONE IN LAMP STUDY

	Cranberry Pond	Woods Lake	Little Simon Pond
Area (ha)	7.2	23	63
Maximum depth (m)	7.6	12	33
Lake-watershed ratio (%)	5	10	10
Residence time (mo)	2	6	15
Liming			
Date	5/85	5/85; 9/86	8/86
Calcite added (1000 kg)	7	23; 35	86
Concentration (mg/L)	34	28; 44	13

Added limestone can neutralize acidity directly, can wash out as a result of water inflows, can affect ion exchange with sediment, or can be coated by other chemicals in the lake and thereby inactivated. Consequently, the amount of limestone that is added varies with lake characteristics.

In the LAMP experiments, techniques are under development to optimize these treatments. During this process, Woods Lake has been treated twice, and the other two bodies of water, once.

The two smaller lakes—Cranberry Pond and Woods Lake—were treated first. Treatments were begun at the end of May 1985, about two months after snowmelt and one month after the breakup of ice cover. They were treated with a very fine particle slurry powder (70% solids in water; 2 μm median particle diameter; 98% pure $CaCO_3$, containing a 0.15 wt% sodium polyacrylate dispersant to maintain suspension). A helicopter with a rotating multiport nozzle sprayed the slurry onto areas of the water surfaces selected to achieve uniform distribution. Samples collected 24 hours after liming from widely dispersed points still showed less than 10% coefficient of variation in ANC.

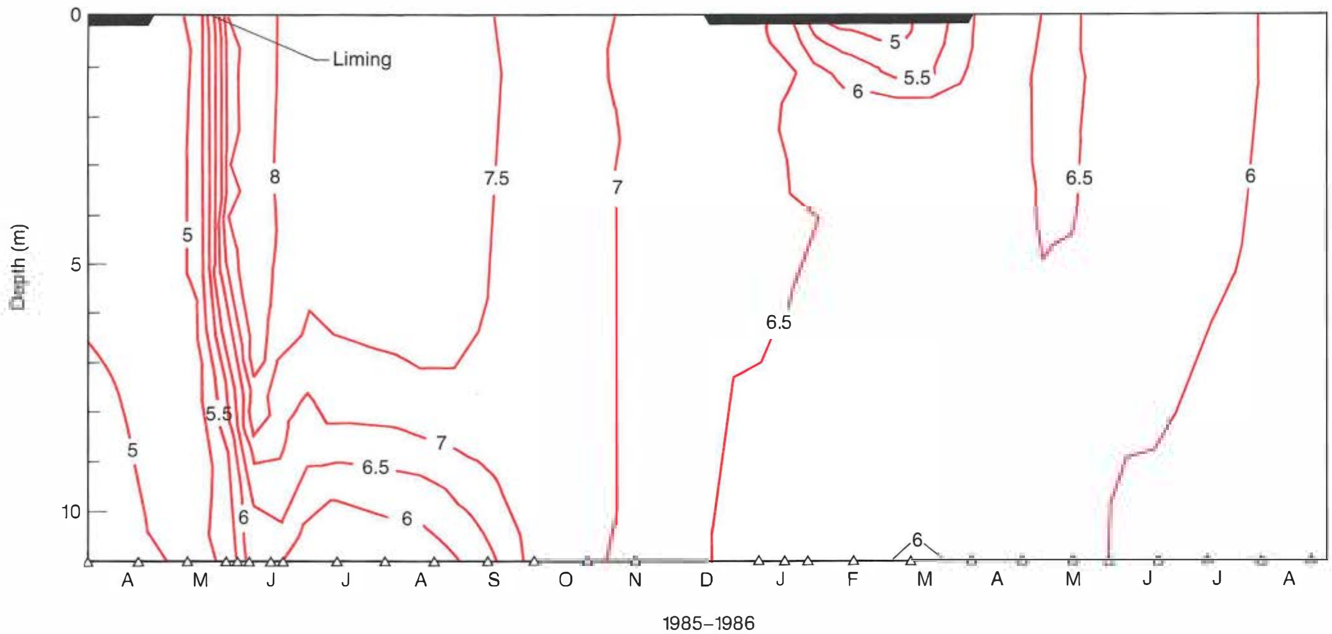
Figure 1 shows the typical pattern of variations in pH with time for Woods Lake, following liming in May 1985. Within a month of liming, dissolution of the calcite was almost complete, and the water reached a pH of about 7.5. Liming produced initial pH values as high as 9.3 at the surface, as dissolving calcite used all the hydrogen ions and dissolved carbon dioxide. However, there were no observable effects on fish exposed in cage bioassays to the abrupt increase in pH from about 5 to greater than 9.

At the time of liming, Woods Lake was stratified, and the liming particles were too fine to penetrate into the high-density layer of the deepest hole of Woods Lake. As a result, this last 5% of lake volume was not neutralized until the fall turnover, when the lake was completely mixed. Even so, measurable ion exchange occurred in the sediments of both Cranberry Pond and Woods Lake.

Reacidification of the limed waters was simulated accurately by a lumped parameter model developed by LAMP, the acid lake reacidification model (ALARM). The model accommodates most of the important processes that affect the chemical responses of lake water to liming, including the exchange of calcium with sediment acidity. Ongoing investigations will compare results from ALARM with results from simulations with EPRI's ILWAS model (RP1109, RP2174).

The most important process controlling the reacidification rate is hydraulic residence time. Inflowing waters displace limed waters, thereby washing out calcium ions and ANC. For example, the ANC of Cranberry Pond returned to its original value within 6 months of the liming treatment, whereas the ANC of Woods Lake was still

Figure 1 Equal-value pH lines at Woods Lake after liming with calcite slurry at end of May 1985. Note the rapid increase in pH at time of liming and the decreases in pH with depth. The dark areas at the top of the plot indicate ice. Surface pH was above 9 immediately after liming, as acidity and CO_2 were consumed during the neutralization reactions.



positive when the second liming was done almost 16 months later. The reacidification time markedly increases with increased residence time and less markedly with increased sediment dosage. These principles were applied in the subsequent limings of Woods Lake and Little Simon Pond during the late summer of 1986.

The hydraulic residence time is fixed for each lake and cannot easily be changed. As noted above, however, the reacidification time can be extended by increasing the sediment dose. Several preparations of limestone, each having larger particles than those used in the May 1985 treatment, were applied, again using a helicopter to spread the slurry. Neither Woods Lake nor Little Simon Pond has yet reacidified.

Woods Lake was treated with 50% more limestone in 1986 than in 1985. Almost 18 months later, the ANC of Woods Lake remains well above the level at which the lake would require another liming. Obviously, the increased sediment treatment was effective in extending the time between treatment and reacidification. Little Simon Pond, which is much bigger than either Cranberry Pond or Woods Lake, was treated with significantly more calcite (Table 1). However, because the initial concentration in the pond was less than that in the other two, retreatment will be necessary by summer 1988.

In all these waters, there was a marked and rapid decrease in inorganic monomeric aluminum after liming. The likelihood of fish toxicity was therefore substantially reduced. During the reacidification of Cranberry Pond, no unusual concentrations of aluminum or other metals were noted.

Effects of liming

Cranberry Pond has the shortest residence time of the three bodies of water that were treated and was expected to reacidify rapidly after liming. Generally, such a body of water would not be limed by direct application of the liming agent to the lake. In Sweden, for example, mechanical devices for adding limestone powders to tributaries of such lakes have been used.

After liming, Cranberry Pond was stocked with brook trout, and sampling and analyses were performed until the lake had reacidified. At that time, most studies of Cranberry Pond were completed. The experience gained at Cranberry Pond showed that the liming treatment was successful: the survival rate of caged brook trout after liming was equal to that of controls; before liming, the caged trout died within 48 hours of being put in the lake. Moreover, the stocked fish fared well, exhibiting good condition and some growth until the ANC within the pond decreased sharply during fall storms. One of those was a tropical storm, having rainfall with a pH greater than 5. In this case, almost all the loss in ANC during that storm was the result of dilution and washout, not reaction with incoming acidic waters. Many of the fish left the lake during the fall, and within six months after liming, the lake had returned to its original pH.

Extensive changes in the biota of limed lakes are expected because the chemical changes allow more species suited to near-neutral pH conditions to survive and compete. However, the major ecologic changes were associated with the introduction of brook trout by stocking. For example, trout predation of existing zooplankton populations caused the disappearance of *Chaoborus americanus* larvae, a zooplankton predator, and the appearance of small cladocerans. It is reasonable to assume that predation by trout, not effects of the changed water quality, was responsible for these conditions.

In the first liming of Woods Lake (1985), as in that of Cranberry Pond, there was very little treatment of bottom sediment. Because the pH and ANC remained high in Woods Lake until the second liming 16 months later, biologists observed substantial growth and spawning of the stocked fish. Again, the fish had a marked effect on the zooplankton and insect life of the lake. The reduced populations of zooplankton may have led to the increases in phytoplankton in the water column that were observed after liming. Increased nutrient concentrations were not observed.

Far fewer brook trout migrated from Woods Lake than from Cranberry Pond. Brook trout spawning was observed over artificial substrates and natural seeps. Whether the artificial substrates were made of granite or limestone, they had no effect on survival and maturation of young life stages. After the second liming, there was a similar pattern. However, increased migration of fish was observed at the lake outlet during spawning season in the fall of 1987. This was associated with high flows, indicating that episodic events were having a deleterious effect on fish behavior. Overall, fish populations in Woods Lake and other limed waters showed productivity similar to that of populations in otherwise similar lakes with near-neutral pH.

Unlike Woods Lake and Cranberry Pond, Little Simon Pond had a resident fish population, especially lake trout and brook trout. The presence of these fish allowed a better test of the effects of sudden increases of pH, ANC, and calcium on important game species. No effects on the fish were noted, either during or immediately after liming, and no dead fish were observed. On the other hand, observations of fish populations during the 15 months after liming indicate that natural reproduction of lake trout occurred in the lake, although spawning was not observed. As in Woods Lake, heavy spawning activity by brook trout was observed.

Several conclusions stand out from the LAMP studies. First, there is no evidence of deleterious biologic effects of liming. The treatment does restore water quality, leading to productive reproducing fisheries. This confirms the experience of operational liming programs. Second, prediction of the reacidification and other water quality changes in limed acidic lakes has achieved a high degree of sophistication. However, the protection against episodic events (storm and snowmelt runoff) is limited. LAMP investigators are currently preparing a proposal to investigate the efficacy of watershed liming, which may lead to a solution of this problem.

Overhead Electrical Transmission

Cost-effective Foundations for Transmission Lines

by Vito Longo, Electrical Systems Division

ABSTRACT *Costs for installed transmission lines range from $200,000 to $2 million a mile, depending on voltage. Because even incremental savings can result in significant project savings, EPRI's foundation research is pursuing better methods for designing both steel pole and lattice steel transmission structure foundations.*

Transmission lines are all around us, so it is easy to think that they represent mature design technology, particularly design of the foundations on which they rest. Pyramids, cathedrals, skyscrapers, and bridges all rest on foundations, and most of the entire body of knowledge and practice in foundation design concerns those kinds of foundations—the ones for large single structures. Transmission lines, however, have foundation requirements outside the realm of that conventional practice, and these requirements are mentioned only rarely in textbooks.

For example, the design of the foundation for a four-legged lattice steel structure will usually be controlled by wind loading. The net effect of the loading is a force that tries to pull two of the four legs out of the ground.

Wind blowing on a building produces the same sort of loading, but because buildings are so heavy, the uplift component of loading never overcomes a structure's deadweight. Thus, the net load for buildings is always compressive.

A single-pole structure represents still another foundation loading situation. In this case the load tries to rotate the foundation, which causes the structure to lean. Building foundations can fail, which will also cause the building to lean; perhaps the most famous example is the tower at Pisa. This is actually the result of a compressive loading failure—one side of the foundation settles more than the other. In other words, compressive loading differs from the horizontal loading of the foundation sides, which causes lateral or rotational movement.

An additional complication in foundation design is the characterization of soil properties at each construction location. Foundation designs for large single structures do not apply to systems that have components constructed in numerous locations. Extensive subsurface soil investigation for a single site is easier to cost-justify than such testing would be for the typical transmission line system that extends from tens to hundreds of miles and touches the ground only every thousand feet or so.

EPRI research

Over the years numerous models have been proposed for the analysis of foundation types that are commonly employed for transmission line structures. The majority of these models were developed—and in some cases tested—for specific foundation geometries and soil conditions. These models are limited in that they are inadequate for use outside the original control conditions because they do not address all the relevant soil variables and, as a result, are incomplete. The need for complete models and the potential for a significant saving in utility line costs (even with small foundation design improvements) are factors that have motivated EPRI research since 1977.

Research on transmission structure foundation design has produced models that are widely applicable for various soil conditions, as well as for different foundation geometries. Activities can be divided into two broad areas: foundations governed by uplift-compression loading and those governed by moment loading. Projects in the two areas have the following objectives.

- To assess state-of-the-art models and identify a unified foundation model
- To collect test data to verify each proposed model
- To promote use of the model in practice

The research has yielded significant results. The report of the uplift-compression assessment activities, conducted by the Geotechnical Engineering Group at Cornell University, is a comprehensive state-of-the-art reference on the engineering of

transmission line structure foundations (EL-2870). This document covers geotechnical planning, site investigation, laboratory testing, capacity analysis, movement analysis, load test evaluation, and soil-structure interaction.

The collection of test data to support any design model for transmission line foundations was a significant undertaking. Although individual utilities and others had conducted tests that might be germane to this work, no repository for the test data existed. The researchers compiled a major reference of 804 static, axial, and field load tests on drilled shafts, driven piles, backfilled foundations, and anchors (EL-3160). In a companion publication, the test data were used for a critical assessment of the state of practice (EL-3771). This assessment identified areas where practice could be improved for both immediate application and long-term design advancement.

Some research is complete; some is still in progress. Test data from both large- and small-scale model tests are supplementing the information not available in documented tests. A unique source for data is a sophisticated, nonlinear, three-dimensional, finite-element computer program for conducting numerical experiments. Researchers are using the physical and numerical experiments to explain quantitative results and to explore areas where no data exist.

GAI Consultants is using the procedure described above for its research on the high overturning moment foundation (RP1280). The significant exception is in test data collection. Utility use of single poles has been limited historically to wood structures. In typical applications, the wood—not the soil system—limits the allowable structure loading. The use of higher-strength steel and concrete poles permits higher loadings that can fail the soil system. Because the use of steel poles was relatively new when this research was undertaken, no large pool of existing data could be assembled.

The state-of-practice review clearly indicated the need for a better model. Utility interest resulted in the construction and testing of 14 full-scale foundations and the development of an analytic model, referred to as a four-spring subgrade modulus (EL-2197). This work on drilled-shaft foundations has been extended to direct-embedment foundations with another set of full-scale tests. The research documentation for this latest work is in progress.

The most visible results of the research are the MFAD (moment foundation analysis and design) and CUFAD (compression-uplift foundation analysis and design) computer programs that are an integral part of the TLWorkstation* software package. These software products have helped several utilities save on total transmission line costs. Philadelphia Electric, Jersey Central Power and Light, and Salt River Project have reported savings of over a million dollars each on projects that were not exceptionally large.

*TLWorkstation is an EPRI trademark.

Future contributions

A comprehensive manual for conducting and interpreting drilled-shaft load tests will be published shortly (EL-5915). This manual will provide a critical evaluation of existing approaches and outline recommended procedures for site evaluation, instrumentation, and testing, as well as present procedures for interpreting tests. It will focus on displacement-based criteria rather than on load control criteria. An abbreviated user's field guide is also scheduled for publication.

At present, most site evaluations are conducted in an ad hoc manner by experienced persons who have developed a feel for the process. The first three parts of a four-part analytic study on the use of reliability-based techniques for site investigation will be released shortly (EL-5507, Vols. 1–3). This study may be the first attempt to quantify the many intuitive and qualitative variables involved in site evaluation. It will represent a first step in formalizing the site investigation process by identifying the statistical variables: in situ test procedures, in situ properties measured by field tests, and true in situ soil parameters.

Toxic Substances

Health Risks at a Coal Tar Disposal Site

by Anthony Thrall, Environment Division

For many decades before the 1940s, artificial gas derived from coal was widely used in the United States as a heating fuel. Coal tar, a residue of these coal carbonization processes, was commonly used in roofing materials, road tars, industrial fuels, wood-preserving chemicals, and paints and enamels. But the tar that could not be sold or reprocessed was usually disposed of in shallow ponds or wells near the gas-processing sites and subsequently covered with soil and other materials. Today, utilities and other past and present site owners are assessing the public health risks of these sites.

Coal tar itself has not been designated a hazardous waste, but some of the chemicals contained in it are identified as toxic in the Clean Water Act, the Resource Conservation Recovery Act, and the environmental regulations of some states. As part of its air and water quality research, EPRI is participating in these coal tar risk assessment studies.

ABSTRACT *Before the large-scale availability of natural gas, local gas works processed coal to make a gaseous heating fuel. The coal conversion processes they used left behind large quantities of coal tar, some of which was disposed of in storage ponds near the gas works. Because coal tar contains toxic components, there have been concerns about possible adverse environmental effects at these old coal tar disposal sites. In this study, EPRI's WTRISK computer program, which estimates the environmental impact of substances transported through surface waters and other media, was used to assess possible health effects at one site. Study results show no risks that would require site cleanup or other special precautionary measures.*

As a case in point, one utility recently began to investigate past gas production by companies that the utility had acquired through mergers and consolidations. After identifying a number of coal tar deposit sites, the utility began field investigations for the purpose of determining their potential human health and environmental effects.

At one site containing relatively large deposits of tar, there was evidence of potential groundwater contamination. A plan for a detailed study of the site was submitted to the state department of environmental protection. The objectives of the site investigation were to determine the size and chemical composition of the coal tar deposits; the potential for soil, groundwater, and surface water pollution; and the potential human health risks.

The tar disposed at the study site was the result of gas production that began in the 1880s and ended in the mid 1950s. The gas plant produced about 1.5 million m^3 of gas per year, resulting in an annual tar production rate of about 11.3 km^3. Much of that tar was probably sold, but large amounts remain at the site.

The utility has identified two primary tar deposits at the site: a tar pond in which the tar is approximately 3 m thick, with tar-saturated soil below it, and a lake bed deposit that is about 1.5 m thick, also with tar-saturated soil below the tar deposit. The two deposits cover about 0.4 ha, with a volume of 14,000 m^3.

The tar deposit site is bounded on the west by a flat area sloping down to a floodplain that was a 26-ha lake on a river until a decade ago, when the dam that formed the lake was breached during a storm. The property and land adjacent to the north and south are zoned for residential development, and the land to the east, industrial. These land uses are not expected to change in the foreseeable future.

The composition of coal tar varies but is usually a mixture of the following.

- PAHs (polynuclear aromatic hydrocarbons), such as benzo(a)pyrene, naphthalene, anthracene acenaphthene, and phenanthrene
- Phenolic compounds, including phenol and methylphenols
- Light aromatic compounds, such as benzene, toluene, and the xylenes
- Miscellaneous organics, such as dibenzofuran
- Small quantities of inorganic chemicals, such as iron, lead, copper, zinc, various sulfides, cyanides, and nitrates

The physical characteristics and chemical composition of the tar depend on the kind of coal from which it was derived, the type of carbonization process, and the process temperatures.

Coal tar deposits can exist in four fractions: a solid or semisolid fraction; two liquid fractions (one heavier than water, one lighter); and a water-soluble fraction. The solid or semisolid tars tend to remain where deposited; the heavier-than-water liquid fraction can sink until it reaches an impermeable clay or bedrock layer, at which time it can move horizontally; the lighter-than-water portion floats and therefore can move on the groundwater surface; the water-soluble component dissolves into the groundwater.

The distance to which the liquid fractions can move in the groundwater is a function of several factors. When the liquid fractions are leached from a disposal site, the extent of the subsequent pollution depends on the size of the source; the porosity, permeability, and chemistry of the soil; the local groundwater gradient; and the solubility of the coal tar chemicals. Under some conditions, groundwater contamination can spread over considerable distances, and large tar deposits can continue to contaminate over many years.

Because tar deposits contain so many different organic and inorganic compounds, it is impossible to conduct a detailed health risk analysis of all of them. For practical reasons such analyses must be

Table 1
CRITERIA FOR SELECTING CONSTITUENTS OF COAL TAR FOR STUDY

Constituent	Maximal Measured Concentration in Core Samples ($\mu g/g$)	Possible Health Effect*	Estimated Transport Time: Site to River (yr)
Benzene	370	Leukemia	70
Toluene	370	Fetal malformation	150
Naphthalene	30,000	Not identified	700
Xylene	360	Fetal malformation	800
Phenanthrene†	18,000	Gastric tumors	9500

*Determined from literature survey.

†In the absence of toxicity data for phenanthrene, investigators used data for benzo(a)pyrene, or B(a)P. This substitution produces conservative results because B(a)P has the greatest toxicity of the PAHs whose toxicity is established.

limited to a few important chemicals representative of most of the tar constituents.

The project team selected chemicals to study on the basis of the following criteria: their presence in the deposits in significant concentrations; their known potential to cause human health or environmental risk; and their ability to travel through the groundwater to reach the river at different rates. This led to five chemicals: benzene, toluene, xylene, naphthalene, and phenanthrene (Table 1).

The study investigated several environmental pathways through which the coal tar site could affect human health, including movement of contaminated groundwater into surface water, atmospheric emissions of volatile pollutants, and ingestion of or skin contact with contaminated soil and dust from the site. For each pollutant, the investigators studied how the pollutant was transported and its fate, possible exposure pathways, characteristics of the exposed population, and the nature and extent of adverse chronic health effects.

Investigators sampled the tar, soil, and groundwater to estimate pollutant transport, and they used models to estimate pollutant transport to adjacent surface waters. To estimate the overall exposure from these pathways and the resulting incremental effect on human health, analysts used EPRI's WTRISK program as a general framework for modeling a substance from its source to its eventual effects on human health (*EPRI Journal*, January/February 1987, p. 52). The model was especially developed to estimate substance transport through surface water, but it accommodates other transport models as well.

To obtain upper bonds on the health effects of the pollutants, investigators conducted a sensitivity analysis. That is, pollutant concentrations in the air, surface water, soil, and dust were determined for a number of alternative cases, which were designed to reflect the basic uncertainty in many assumptions, parameters, and input values. For each alternative case, the study team determined the exposed population, the exposure rates for each pollutant, and the consequent health risks.

The study showed that emissions of the five selected pollutants from the tar deposit site pose little risk to the surrounding environment and population. Surface water concentrations of the pollutants were estimated to be low; moreover, the river water is used neither for drinking nor for irrigation, thus further mitigating any potential health hazard. The estimated risk from fish and shellfish consumption was not significant. It might be noted, however, that the potential risk would increase if in the future the quality of the river water were to be improved sufficiently to make it potable. At that time, a more thorough examination of the risk from all pollutants found at the site would be justified.

Should the site be disturbed by excavation or construction activities, benzene and other volatile pollutants would probably be emitted to the air at higher rates than they are now. Moreover, contaminated soil and dust would be picked up by winds and carried into the surrounding neighborhood. But on the basis of the risk calculations, neither of these situations would pose a significant health hazard to the nearby population. Emission rates would continue to be low and dispersion throughout the environment would maintain exposure rates below measurable or hazardous levels. Of course, exposure to benzene, phenanthrene, and other PAHs could be higher for personnel working at the disposal site over long periods unless appropriate precautions were taken.

The site is fenced to prevent children from playing near or on the tar pond, and that precaution should be maintained. Finally, the risk analysis indicates that neither excavation of the coal tar nor other remedial action is necessary, and therefore none is planned.

The WTRISK transport model is one of several analytic tools being developed by EPRI to help utilities assess the potential risks of old coal tar disposal sites. WTRISK proved useful in this case study and is likely to be useful for assessing the health risks at other coal tar disposal sites. There appears to be considerable variation from one site to another, however, and the estimates of health risks are highly dependent on the composition of the coal tar and the conditions of human exposure. Because of these variations, further case studies are necessary in order to develop strategies to help utilities manage this source of potential pollutants.

The WTRISK code is available from the Electric Power Software Center. Updated documentation for the code and a detailed report on the case study are being prepared and will be available this fall.

New Contracts

Project	Funding/ Duration	Contractor/EPRI Project Manager
Advanced Power Systems		
Evaluation: Coal Liquefaction Process (RP832-21)	$49,359 4 months	Bechtel Group, Inc./ *B. Louks*
Gasification Test: Pittsburgh No. 8 Coal (RP1654-39)	$498,412 15 months	Gesellschaft für Kohle-Technologie mbH/ *N. Hertz*
Secondary Reactions: Desulfurization by the Claus Reaction on a Cold Bed of Catalyst (RP1654-43)	$54,279 7 months	Black & Veatch/*N. Hertz*
Off-Design Turbine Operation Model (RP2565-16)	$38,000 5 months	Power Technologies, Inc./ *A. Cohn*
Application: GATE Code to Future Gas Turbine Systems (RP2620-5)	$35,314 8 months	Encotech, Inc./*A. Cohn*
Characterization: Coal/Oil Agglomerate Fuels (RP2655-26)	$616,385 18 months	Combustion Engineering, Inc./*W. Rovesti*
Modification of FT4 for Steam Injection (RP2832-1)	$156,578 8 months	Turbo Power and Marine Systems, Inc./*A. Cohn*
Evaluation: Utility Gas Turbine Blade Temperature Pyrometer (RP2985-6)	$25,000 32 months	Salt River Project/ *H. Schreiber*
Coal Combustion Systems		
Fabrication and Testing of SO_2 Oxidation Catalyst (RP724-6)	$26,958 9 months	SRI International/ *R. Altman*
Fundamental Hydrodynamics of a Circulating Fluidized Bed (RP979-21)	$78,524 11 months	Massachusetts Institute of Technology/*S. Ehrlich*
Cyclone Boiler Retrofit With Low NO_x/SO_x Burner (RP1030-45)	$50,000 6 months	TransAlta Resources Investment Corp./ *A. Kokkinos*
Assessment: Asbestos Insulation Substitutes for Steam Lines in Fossil Fuel Power Plants (RP1266-50)	$39,820 9 months	University of Tennessee/ *J. Tsou*
Fluidized-Bed Combustion of Refuse-Derived Fuel (RP2190-3)	$107,423 4 months	Babcock & Wilcox Co./ *C. McGowin*
Solidification Process of Metal Matrix–Fly Ash Particle Composites (RP2422-18)	$202,890 45 months	University of Wisconsin/ *D. Golden*
Design Improvement: Flue Gas Desulfurization Retrofit (RP2873-1)	$250,900 11 months	Sargent & Lundy/*C. Dene*
Engineering Evaluation of Combined No_x-SO_2 Controls (RP3004-1)	$388,143 2 years	Sargent & Lundy/ *E. Cichanowicz*
Electrical Systems		
Reliable Cooling Control System for Advanced Valve (RP1291-6)	$50,000 8 months	CGEE Alsthom North America, Inc./*B. Damsky*
Methods of Measuring Transmission Utilization (RP2473-26)	$74,872 5 months	Casazza, Schultz & Associates, Inc./*R. Iveson*
On-Line Methods for Determining Transmission Utilization (RP2473-27)	$74,992 10 months	Casazza, Schultz & Associates, Inc./*R. Iveson*
Design: Power Line Magnetic Field Characterization (RP2942-1)	$97,073 8 months	Electric Research & Management, Inc./*J. Mitsche*
Design: Magnetic Field Sources and Characteristics (RP2942-2)	$247,853 13 months	Enertech Consultants, Inc./*J. Mitsche*

Project	Funding/ Duration	Contractor/EPRI Project Manager
Energy Management and Utilization		
Indoor Air Quality (RP2034-25)	$49,981 1 year	Geomet Technologies, Inc./*J. Kesselring*
Effects of Oxide Dispersions on the High-Temperature Oxidation Behavior of Alloys (RP2278-9)	$124,014 16 months	Battelle, Columbus Division/*J. Stringer*
Retrofitting Space Conditioning Systems for Cool Storage (RP2732-18)	$65,752 10 months	Denkmann Thermal Storage, Ltd./*D. Geistert*
Improved Phase-Change Materials for Cool Storage (RP2732-19)	$109,149 16 months	Transphase Systems, Inc./*D. Geistert*
Room Air Diffusion With Low-Temperature Air Distribution (RP2732-20)	$69,575 17 months	Kansas State University/*D. Geistert*
Assessment of Unitary Cool Storage Systems (RP2732-21)	$67,721 11 months	Ayres Ezer Lau, Inc./ *D. Geistert*
Air Conditioning Systems—Options for Electric Vehicles (RP2861-3)	$49,783 7 months	Arthur D. Little, Inc./ *G. Purcell*
Impact Project Data Integration (RP2863-5)	$59,985 10 months	Applied Management Sciences, Inc./*S. Braithwait*
Workshop and R&D Plant Office Worker Productivity (RP2891-7)	$91,311 10 months	W. I. Whiddon & Associates, Inc./*M. Blatt*
Infrared Drying of Textile Yarn (RP2893-8)	$38,458 10 months	Auburn University/ *K. Amarnath*
Advanced Power Electronics Development Research (RP2918-3)	$398,670 23 months	Tennessee Center for Research & Development/ *B. Banerjee*
End-Use Power Quality: Methodologies for Assessments and Improvements (RP2935-12)	$64,306 10 months	Electrotek Concepts, Inc./ *M. Samotyj*
Fluid-Elastic Excitation in Heat Exchanger Tubes (RP8006-12)	$75,000 34 months	Oklahoma State University/*D. Steininger*
Assessment of Energy Productivity Applications of Superconductors (RP8009-2)	$495,000 6 months	Martin Marietta Energy Systems,Inc./*T. Schneider*
Environment		
Incorporation of Semiempirical Long-Range Transport Models Into the Spatial Analysis of Acid Precipitation Data (RP2434-7)	$92,133 1 year	ERT A Resource Engineering Co./*D. Hansen*
Conference: Electromagnetic Radiation and Circadian Rhythmicity (RP2965-4)	$101,448 1 year	Institute for Circadian Physiology/*C. Rafferty*
Nuclear Power		
Stress Corrosion Cracking Susceptibility of Multipass 308 Stainless Steel Welds (RP2059-7)	$100,000 10 months	University of California/ *W. Childs*
Software Simulation of Ultrasonic Interactions With CCSS and Guidelines for CCSS Inspection (RP2405-25)	$98,000 8 months	Drexel University/*M. Avioli*
Influence of Irradiation and Stress/Strain on In-Reactor Behavior of Various High-Purity Stainless Steels (RP2680-8)	$574,450 37 months	Siemens-Aktiengesellschaft/*L. Nelson*
Steam Generator Tube Plugging (RPS404-12)	$32,239 13 months	Energy Management Services, 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 SYSTEMS

Economics of Phased Gasification–Combined-Cycle Plants: Generic System Results
AP-5467 Final Report (RP2699-4); $25
Contractor: Zaininger Engineering Co., Inc.
EPRI Project Managers: A. Lewis and M. Gluckman

Materials and Devices for Power Electronic Applications
AP/EM/EL-5470 Final Report (RP1996-20); $32.50
Contractor: Steitz and Associates
EPRI Project Managers: F. Goodman, B. Banerjee, H. Mehta

Capital Cost Assessment of Phosphoric Acid Fuel Cell Power Plants for Electric Utility Applications
AP-5608 Final Report (RP1777-1); $25
Contractor: International Fuel Cells Corp.
EPRI Project Managers: D. Rastler and C. Siebenthal

Low-Porosity Rock Cavern Design Concepts for Compressed-Air Energy Storage
AP-5689 Final Report (RP2488-6); $32.50
Contractor: Ulf E. Lindblom
EPRI Project Manager: B. Mehta

Devon Station Repowering Study, Vols. 1 and 2
AP-5701 Final Report (RP2565-3); Vol. 1, $47.50; Vol. 2, $47.50
Contractor: Northeast Utilities Service Co.
EPRI Project Manager: H. Schreiber

Gas Turbine Procurement: 1987 Workshop
AP-5702 Final Report (RP2565-6); $47.50
Contractor: Energy Systems Associates
EPRI Project Manager: H. Schreiber

Evaluation of Hard-Rock-Cavern Construction Methods for Compressed-Air Energy Storage
AP-5717 Final Report (RP2488-11); $32.50
Contractor: Fenix & Scisson, Inc.
EPRI Project Manager: B. Mehta

Photovoltaic Field Test Performance Assessment: 1986
AP-5762 Final Report (RP1607-6); $32.50
Contractor: New Mexico Solar Energy Institute
EPRI Project Manager: J. Schaefer

Evaluation of a Once-Through Heat Recovery Steam Generator Concept
AP-5772 Final Report (RP2653-9); $25
Contractor: Arinc Research Corp.
EPRI Project Manager: H. Schreiber

Measurement of Air Solubility in an Unlined Air-Cushion Rock Cavern
AP-5805 Final Report (RP2488-9); $32.50
Contractor: Norwegian Hydrotechnical Laboratory
EPRI Project Manager: B. Mehta

Improved Maintainability for Advanced Gas Turbines
AP-5822 Final Report (RP2531-1); $32.50
Contractor: Dow Engineering Co.
EPRI Project Managers: C. Dohner and R. Frischmuth

COAL COMBUSTION SYSTEMS

Dissimilar-Weld Failure Analysis and Development, Vol. 7: Prediction of Damage in Service (PODIS) Code
CS-4252 Final Report (RP1874-1); $200
Contractor: The Materials Properties Council, Inc.
EPRI Project Managers: R. Townsend and R. Viswanathan

Nonradioactive Tracer for Steam Turbine Thermal Performance Tests
CS-5486 Final Report (RP1878-1); $32.50
Contractor: General Electric Co.
EPRI Project Managers: J. Tsou and T. McCloskey

Periodic Vibration Monitoring: Utility Experience
CS-5517 Final Report (RP1864-4); $200
Contractor: Computational Systems, Inc.
EPRI Project Manager: J. Scheibel

Deep Cleaning Pittsburgh Seam Coal for Sulfur Dioxide Reduction
CS-5549 Interim Report (RP1400-6, -11); $200
Contractors: Kaiser Engineers, Inc.; Science Applications International Corp.
EPRI Project Managers: C. Harrison and J. Hervol

Guidelines for Fireside Testing in Coal-Fired Power Plants
CS-5552 Final Report (RP1891-3); $520
Contractor: Energy and Environmental Research Corp.
EPRI Project Manager: A. Mehta

Condition Monitoring of Fans With Rolling Element Bearings
CS-5606 Final Report (RP734-4); $32.50
Contractor: Battelle, Columbus Division
EPRI Project Manager: J. Scheibel

Cleaning Lower and Middle Kittanning Seam Coals for Sulfur Removal Before and After Blending
CS-5642 Interim Report (RP1400-6, -11); $200
Contractors: Kaiser Engineers, Inc.; Science Applications International Corp.
EPRI Project Managers: C. Harrison and J. Hervol

Coal Cleaning to Improve Hub Seam Combustion Economics
CS-5646 Interim Report (RP1400-6, -11, -13); $400
Contractors: Kaiser Engineers, Inc.; Science Applications International Corp.; Combustion Engineering, Inc.
EPRI Project Managers: J. Hervol, A. Mehta, C. Harrison

Sulfur Meter for Blending Coal at Plant Monroe
CS-5651 Final Report (RP2459-1); $200
Contractor: Detroit Edison Co.
EPRI Project Manager: D. O'Connor

Condenser Performance Test and Replacement Tubing Material Evaluation
CS-5662 Final Report (RP1689-8); $200
Contractor: Heat Exchanger Systems, Inc.
EPRI Project Manager: J. Tsou

Proceedings: Fish Protection at Steam and Hydroelectric Power Plants
CS/EA/AP-5663-SR Proceedings; $250
EPRI Project Managers: W. Micheletti, J. Mattice, C. Sullivan

Slag Monitoring for Utility Boilers
CS-5692 Final Report (RP1893-5); $200
Contractors: Battelle, Columbus Division; Central Electricity Generating Board
EPRI Project Manager: J. Scheibel

ELECTRICAL SYSTEMS

TLWorkstation Code: Version 1.1, Vol. 6: TLOP/SAGT Manual, Rev. 1
EL-4540-CCM Computer Code Manual (RP2151-1); $55
Contractor: Power Technologies, Inc.
EPRI Project Manager: R. Kennon

Fault Location for Transmission-Type Cables
EL-5643 Final Report (RP7874-1); $32.50
Contractor: Hughes Research Laboratories
EPRI Project Managers: F. Garcia and T. Rodenbaugh

Controller for Real and Reactive Power Modulation of HVDC Systems
EL-5657 Final Report (RP1426-2); $25
Contractor: General Electric Co.
EPRI Project Manager: S. Nilsson

Lightning Flash Characteristics: 1986
EL-5667 Interim Report (RP2431-1); $25
Contractor: State University of New York at Albany
EPRI Project Manager: J. Mitsche

A 4000-A HVDC Circuit Breaker With Fast Fault-Clearing Capability
EL-5668 Final Report (RP1507-4); $32.50
Contractor: BBC Brown Boveri, Inc.
EPRI Project Manager: J. Porter

A Joint Utility Investigation of Unexplained Transmission Line Outages
EL-5735 Final Report (RP2335-1); $40
Contractors: Sierra Pacific Power Co.; Bonneville Power Administration; Pacific Power & Light Co.; Idaho Power Co.
EPRI Project Manager: V. Longo

Small Signal Stability Program Package, Vols. 1 and 2
EL-5798 Final Report (RP2447-1); Vol. 1, $32.50;
EL-5798-CCML Vol. 2, Computer Code Manual
Contractor: Ontario Hydro
EPRI Project Manager: M. Lauby

Demonstration of a Broadcast Radio System for Distribution Automation, Vols. 1 and 2
EL-5799 Final Report (RP1535-3); Vol. 1, $25; Vol. 2, $47.50
Contractor: McGraw-Edison Power Systems
EPRI Project Manager: W. Shula

Database Management for Power System Planning
EL-5804 Final Report (RP2668-2); $32.50
Contractor: Carlsen and Fink Associates, Inc.
EPRI Project Manager: M. Lauby

Eddy-Current Technique for Nondestructive Evaluation of Generator Retaining Rings
EL-5814 Interim Report (RP2719-1); $25
Contractor: J. A. Jones Applied Research Co.
EPRI Project Manager: J. Stein

ENERGY MANAGEMENT AND UTILIZATION

Residential, Commercial, and Agricultural Technology Alternatives for Rural Electric Systems
EM-5567 Final Report (RP2788-8); $300
Contractors: National Food and Energy Council; Battelle, Columbus Division
EPRI Project Managers: C. Gellings, W. Smith, O. Zimmerman

Customer Response to Interruptible and Curtailable Rates, Vols. 1–3
EM-5630 Final Report (RP2343); Vol. 1, $1000; Vol. 2, Final Report; Vol. 3, Computer Code Manual
Contractor: Laurits R. Christensen Associates, Inc.
EPRI Project Manager: P. Hanser

Home Automation Technology Directory
EM-5699 Final Report (RP2830-6); $99
Contractor: Parks Associates
EPRI Project Manager: V. Rabl

Commercial End-Use Data Development Handbook: COMMEND Market Profiles and Parameters, Vols. 1 and 2
EM-5703 Interim Report (RP2863-1); Vol. 1, $25; Vol. 2, $40
Contractor: Regional Economic Research, Inc.
EPRI Project Manager: S. Braithwait

Innovative Rate Design Survey: 1986
EM-5705 Final Report (RP2381-5); $300
Contractor: Ebasco Business Consulting Co.
EPRI Project Manager: W. Smith

DSM Program Monitoring
EM-5706 Final Report (RP2548-1); $1000
Contractors: Applied Management Sciences, Inc.; Battelle, Columbus Division
EPRI Project Managers: S. Braithwait and W. Smith

Cold Air Distribution Design Guide
EM-5730 Final Report (RP2732-3); $150
Contractor: Dorgan Associates, Inc.
EPRI Project Manager: R. Wendland

Selected Papers on Demand-Side Management: 1985–1987
EM-5732 Proceedings (RP2548-1); $62.50
Contractors: Synergic Communication Services, Inc.; Battelle, Columbus Division
EPRI Project Manager: W. Smith

DSM Residential Customer Acceptance, Vols. 1 and 2
EM-5766 Final Report (RP2548-1); Vol. 1, $1000; Vol. 2, $1000
Contractors: Synergic Resources Corp.; Heberlein & Baumgartner Research Services; Battelle, Columbus Division
EPRI Project Managers: S. Braithwait and W. Smith

Assessment of Building Codes, Standards, and Regulations Affecting Add-On and Dual-Fuel Heat Pumps
EM-5791 Final Report (RP2033-21); $32.50
Contractor: National Conference of States on Building Codes and Standards, Inc.
EPRI Project Managers: C. Hiller, P. Fairchild, J. Calm, P. Joyner

ENVIRONMENT

Proceedings: Seminar on Remote Sensing of Forest Decline Attributed to Air Pollution
EA-5715 Proceedings (RP2661-19); $40
Contractor: International Institute for Applied Systems Analysis
EPRI Project Manager: C. Hakkarinen

Environmental Behavior of Organic Substances
EA-5740-SR Special Report; $25
EPRI Project Managers: I. Murarka and J. Guertin

Chromium Reactions in Geologic Materials
EA-5741 Interim Report (RP2485-3); $47.50
Contractor: Battelle, Pacific Northwest Laboratories
EPRI Project Manager: I. Murarka

EXPOCALC Ver. 2.1: An Exposure Assessment Tool for Transmission Line Electric and Magnetic Fields
EA-5765-CCML Computer Code Manual (RP799-16)
Contractor: Enertech Consultants
EPRI Project Manager: S Sussman

NUCLEAR POWER

Stress Corrosion Cracking of LWR Fuel, Vol. 2: The SCCIG-B Model
NP-1798 Final Report (RP2061-1); $32.50
Contractor: Stanford University
EPRI Project Managers: S. Gehl and D. Franklin

VIPRE-01: A Thermal-Hydraulic Code for Reactor Cores, Vol. 5: Guidelines
NP2511-CCM Computer Code Manual (RP1584-1); $32.50
Contractor: Battelle, Pacific Northwest Laboratories
EPRI Project Manager: G. Srikantiah

The Reactor Analysis Support Package (RASP), Vol. 9: BWR Stability Analysis
NP-4498 Final Report (RP1761-1); $32.50
Contractor: S. Levy, Inc.
EPRI Project Manager: L. Agee

Commercial-Grade Motors in Safety-Related Applications
NP-4917 Final Report (RP1707-37); $500
Contractor: Strategic Technology and Resources
EPRI Project Manager: G. Sliter

Utility Guide to Advanced Ultrasonic Systems for Preservice and In-Service Inspections, Rev. 1
NP-5086 Rev. 1 Topical Report (RP2057-6); $32.50
Contractor: VinTek, Inc.
EPRI Project Manager: M. Avioli

Surface Treatments to Reduce Radiation Fields
NP-5209-SR Special Report; $40
EPRI Project Manager: H. Ocken

Evaluation of Fuel-Cladding Properties at High Temperatures
NP-5427 Final Report (RP1577-4); $25
Contractor: The S. M. Stoller Corp.
EPRI Project Manager: D. Franklin

BWR Radwaste Precoat Filter Optimization
NP-5483 Final Report (RP2414-15); $500
Contractor: Vance & Associates
EPRI Project Manager: P. Robinson

Library of PWR Steam Generator Tubing Samples
NP-5503 Final Report (RPS301-5); $40
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: C. Welty

MULTEQ: Equilibrium of an Electrolytic Solution With Vapor-Liquid Partitioning and Precipitation, Vols. 1–3
NP-5561-CCM Vol. 1, Computer Code Manual; NP-5561-CCML Vol. 2, Computer Code Manual (RPS407-5); Vol. 1, $25; Vol. 3, forthcoming
Contractor: S-Cubed
EPRI Project Manager: J. Paine

Modeling of Ground-Motion Attenuation in Eastern North America
NP-5577 Final Report (RP2556-6); $55
Contractor: Woodward-Clyde Consultants
EPRI Project Managers: C. Stepp and J. King

Sourcebook for Microbiologically Influenced Corrosion in Nuclear Power Plants
NP-5580 Final Report (RP2812-2); $300
Contractor: Structural Integrity Associates, Inc.
EPRI Project Managers: N. Hirota and D. Cubicciotti

Microstructural Examination of Fatigue Accumulation in Critical LWR Components
NP-5590 Final Report (RP2614-9); $32.50
Contractor: United Kingdom Atomic Energy Authority
EPRI Project Manager: M. Lapides

Precipitate Stability in Zircaloy-4
NP-5591 Final Report (RP1250-16); $25
Contractor: General Electric Co.
EPRI Project Manager: A. Machiels

Evaluation of Steam Generator Chemical Hideout at the Prairie Island PWR
NP-5592 Final Report (RP2599-1); $25
Contractor: NWT Corp.
EPRI Project Managers: S. Hobart and C. Welty

Effects of Alternate pH Control Additives on PWR Secondary Cycle Chemistry
NP-5594 Final Report (RP2599-1); $32.50
Contractor: NWT Corp.
EPRI Project Managers: S. Hobart and C. Welty

Elastic-Plastic Fracture Analysis of Through-Wall and Surface Flaws in Cylinders
NP-5596 Final Report (RP1237-5); $25
Contractor: General Electric Co.
EPRI Project Manager: D. Norris

Aerosol Deposition in BWR Steam Separators and Dryers
NP-5597 Final Report (RP2120-2); $25
Contractor: Battelle, Columbus Laboratories
EPRI Project Manager: M. Merilo

Computer-Assisted Design of a PWR Digital Control System
NP-5598 Final Report (RP2126-8); $32.50
Contractor: Integrated Systems Inc.
EPRI Project Manager: D. Cain

Evaluation of Aerosol Correlations
NP-5602 Final Report (RP2684-1); $25
Contractor: Rockwell International Corp.
EPRI Project Manager: R. Ritzman

The 1986 North Palm Springs Earthquake: Effects on Power Facilities
NP-5607 Final Report (RP2848); $25
Contractors: EQE Inc.; Bechtel Power Corp.
EPRI Project Manager: R. Kassawara

Procedures for Treating Common Cause Failures in Safety and Reliability Studies, Vols. 1 and 2
NP-5613 Final Report (RP2169-4); Vol. 1, $40
Contractor: Pickard, Lowe and Garrick, Inc.
EPRI Project Manager: D. Worledge

Investigation of the San Salvador Earthquake of October 10, 1986: Effects on Power and Industrial Facilities
NP-5616 Final Report (RP2848-6); $25
Contractor: EQE Inc.
EPRI Project Manager: R. Kassawara

Recommended Piping Seismic-Adequacy Criteria Based on Performance During and After Earthquakes, Vols. 1 and 2
NP-5617 Final Report (RP2635-1); Vol. 1, $25; Vol. 2, $32.50
Contractor: EQE Inc.
EPRI Project Manager: Y. Tang

Enhancing Plant Effectiveness Through Improved Organizational Communication
NP-5618 Final Report (RP2167-3); $40
Contractor: Essex Corp.
EPRI Project Manager: H. Parris

Stability Analysis Model for BWR Applications (SAMBA), Vols. 1-4
NP-5620-CCML Computer Code Manual (RP1384-1)
Contractor: ASEA-Atom
EPRI Project Manager: S. Kalra

Cleanup of Steam Cycle Drains in PWRs With Once-Through Steam Generators
NP-5621 Final Report (RP1571-5); $25
Contractors: Gibbs & Hill, Inc.; NWT Corp.
EPRI Project Manager: T. Passell

PWR Pressure Vessel Neutron Spectra at McGuire-1
NP-5622 Final Report (RP827-4); $32.50
Contractor: University of Missouri—Rolla
EPRI Project Manager: T. Passell

Oxygen Control in PWR Makeup Water
NP-5623 Final Report (RP2297-1); $25
Contractor: Central Electricity Generating Board
EPRI Project Manager: T. Passell

Chemistry Data Integration in a PWR
NP-5624 Final Report (RP1571-5); $25
Contractor: NWT Corp.
EPRI Project Manager: T. Passell

Proceedings: 1986 Integrated Power Plant Computer Communications Seminar
NP-5641-SR Proceedings; $55
EPRI Project Managers: R. Colley and M. Divakaruni

EPRI Nondestructive Evaluation Center: Assessment of the ISCC Training and Qualification Program
NP-5658 Interim Report (RP1570-2); $25
Contractor: J. A. Jones Applied Research Co.
EPRI Project Manager: G. Dau

PLANNING AND EVALUATION

Competitive Production Strategies for Existing Power Plants: Illustrative Examples
P-5046-SY Summary Report (RP2074-1); $25
Contractor: Temple, Barker & Sloane, Inc.
EPRI Project Managers: S. Chapel and D. Geraghty

Fuel Contract Mix Model (CONTRACTMIX), Version 1.1: User's Guide and Tutorial
P-5243-CCM Computer Code Manual (RP2359-4, RP2359-20); $40
Contractors: Decision Focus Inc.; Lotus Consulting Group
EPRI Project Manager: H. Mueller

Multiobjective Integrated Decision Analysis System (MIDAS), Vols. 1 and 2
P-5402 Vol. 1, Final Report (RP2317); $25
P-5402-CCM Vol. 2, Computer Code Manual (Version 1.0); $50
Contractors: Temple, Barker & Sloane, Inc.; M. S. Gerber and Associates, Inc.
EPRI Project Manager: H. Chao

DSM Regulatory Impacts
P/EM-5631 Final Report (RP2548-1); $1000
Contractors: Battelle, Columbus Division; Temple, Barker & Sloane, Inc.; The Investor Responsibility Research Center
EPRI Project Managers: K. Miller-Vejtasa and W. Smith

EPRI Fuel Information Access System (EFIAS): Vers. 1.0 Users Guide
P-5724-CCM Computer Code Manual (RP2359-4); $32.50
Contractors: Lotus Consulting Group, Inc.; Putnam, Hayes & Bartlett, Inc.
EPRI Project Managers: H. Mueller and A. Reza

Estimating Short-Term Energy Production Uncertainty
P-5803P Final Report (RP2359-23); $500
Contractor: Applied Decision Analysis, Inc.
EPRI Project Manager: H. Mueller

EXPLORATORY RESEARCH

Center Fracture Toughness of Monoblock Rotors
ER-5619-SR Special Report; $25
EPRI Project Manager: R. Jaffee

Proceedings: First Annual Workshop on Biologic Processing of Coal
ER-5709-SR Proceedings
EPRI Project Manager: L. Atherton

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.

ASK: PCB Economic Risk Management Model
Version 4.0 (IBM PC)
Contractor: Decision Focus, Inc.
EPRI Project Manager: Victor Niemeyer

BETCY: Between Cycle Reload Function
Version MOD (CDC, IBM); NP-4574
Contractor: GRP Consulting
EPRI Project Manager: Walter Eich

COFFEC: Cost of Fuel Failure Evaluation Code
Version 1.0 (IBM PC)
Contractor: The S. M. Stoller Corp.
EPRI Project Manager: Rosa Yang

COIL: Contaminated Oil Economic Risk Management Model
Version 4.0 (IBM PC)
Contractor: Decision Focus, Inc.
EPRI Project Manager: Victor Niemeyer

COOLAID: Thermal Energy Storage/Demand-Side Planning/Load and Market Research
Version 1.1 (IBM PC)
Contractor: Regional Economics Research, Inc.
EPRI Project Manager: Steven Braithwait

CPM-2: Two-Dimensional Lattice Physics Code
Version 3-A (IBM, CDC[BE])
Contractor: S. Levy, Inc.
EPRI Project Manager: Walter Eich

ECCAPP: Power Line Fault Current Coupling to Nearby Natural Gas Pipelines
Version 1.3 (IBM, VAX); EL-5472
Contractor: SES, Inc.
EPRI Project Manager: James Hall

CALENDAR

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

SEPTEMBER

12–15
Fossil Fuel Plant Product Fair
Pittsburgh, Pennsylvania
Contact: Jerry Fourroux (415) 855-2434

15–16
5th Annual Workshop Sponsored by NSAC and Operational Reactor Safety Engineering and Review Groups
San Diego, California
Contact: Bill Reuland (415) 855-2977

19–21
3d National Conference: Environmental and Public Health Effects of Soils Contaminated With Petroleum Products
Amherst, Massachusetts
Contact: Mary McLearn (415) 855-2487 or Gordon Newell (415) 855-2573

21–23
1988 Conference: Electrical Applications of Superconductivity
Orlando, Florida
Contact: Dave Sharma (415) 855-2302

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

OCTOBER

4–6
FASTCHEM and FOWL: Codes for Modeling the Release, Transport, and Fate of Inorganic Chemicals in Groundwater
Washington, D.C.
Contact: Dave McIntosh (415) 855-7918

11–13
Seminar: Fuel Supply
Kansas City, Missouri
Contact: Jeremy Platt (415) 855-2628

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

24–26
Conference: Competitive Cost Management
New Orleans, Louisiana
Contact: Edward Altouney (415) 855-2626

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

NOVEMBER

2–4
2d International Conference on Improved Coal-Fired Power Plants
Palo Alto, California
Contact: John Bartz (415) 855-2851

15–16
9th Annual EPRI NDE Information Meeting
Charlotte, North Carolina
Contact: Soung-Nan Liu (415) 855-2480

16
Metal Chemistry and Bioavailability in Acid Water
Arlington, Virginia
Contact: Don Porcella (415) 855-2723

17–18
8th Reactor Physics Software User's Group
Richmond, Virginia
Contact: Walter Eich (415) 855-2090

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

29–December 1
7th Symposium: Expanding the Role of Forecasting in Utility Planning
Atlanta, Georgia
Contact: Ray Squitieri (415) 855-2630

DECEMBER

7–9
Resolution of Seismic Issues in Low-Seismicity Regions
Orlando, Florida
Contact: Carl Stepp (415) 855-2103

Authors and Articles


Birk

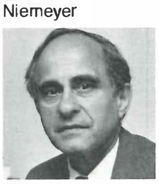

Sullivan


McLearn


Murarka


Niemeyer


O'Brien


Mankoff


Kubicki

Tools of the Trade for Hydro Relicensing (page 4) was written by John Douglas, with technical guidance from two staff members of EPRI's Advanced Power Systems Division.

Jim Birk has been director of the Advanced Conversion and Storage Department since October 1985, following five years as a program manager. He came to EPRI in 1973 after six years as a senior scientist with Rockwell International Corp. Birk graduated in chemistry from Iowa State University and earned a PhD in analytical chemistry at Purdue.

Charles Sullivan heads the Hydroelectric Generation Program, where he has worked for six years. From 1977 to 1982 he was a research manager in the Nuclear Power Division. Before joining EPRI, Sullivan worked successively at Lawrence Livermore Laboratory and for the Reactor Systems Branch of NRC. Sullivan has BS and MS degrees in mechanical engineering from Arizona State University. ■

Strategies for Safe Underground Storage (page 14) was written by David Boutacoff, feature writer for the *Journal,* with technical contributions from staff members of EPRI's Coal Combustion Systems and Environment divisions.

Mary McLearn, a project manager in the CCS Heat, Waste, and Water Management Program since July 1986, earlier worked for two years in the Geothermal Power Systems Program. She joined EPRI in 1984 after four years with the Environmental Monitoring and Services Center of Rockwell International Corp. and four years as an assistant professor of chemistry at Cornell University. McLearn has BA and PhD degrees in chemistry from Skidmore College and the University of Kansas, respectively.

Ishwar Murarka heads the Land and Water Quality Studies Program of the Environment Division. He has managed environmental science research since he came to EPRI in 1979, following five years as an Argonne National Laboratory scientist in environmental assessment. Educated in geography at the University of Calcutta, Murarka has MS and PhD degrees in soil science and statistics from Oregon State University and an MBA from the University of Chicago.

Victor Niemeyer is a technical adviser in the Environmental Risk Analysis Program, developing information and methods for utility use in risk management. He came to EPRI in 1978 after working as a research associate with the University of Texas Center for Energy Studies and Charles River Associates. Niemeyer graduated in economics from the University of California (Berkeley) and earned a PhD at the University of Texas. ■

Heading Off Heat Stress (page 22) was written by Jon Cohen, science writer, aided by **John O'Brien** of EPRI's Nuclear Power Division. O'Brien, an EPRI project manager since 1979, specializes in human factors engineering. He previously worked for five years in man-machine studies at the Westinghouse R&D Center; before that, he was a research analyst at the Center for Occupational Education at North Carolina State University and a research fellow at the Institute of Human Ecology in Raleigh. ■

Building a Framework for Integrated Communications (page 28) was written by Taylor Moore, senior feature writer, with technical assistance from two research managers of EPRI's Electrical Systems Division.

Lawrence Mankoff, a project manager in the Transmission Substations Program, works with system communications, particularly protective measures. He joined EPRI in April 1987 after 38 years with General Electric. Mankoff graduated in engineering physics from Ohio State University.

Bill Kubicki, a project manager in the Distribution Program, has been at EPRI since 1986, specializing in integrated communications for utility systems. He was previously with the Palo Alto (California) Utilities Department for 6 years and had worked for 21 years with a number of aerospace communications and equipment firms. Kubicki has a BS in electrical engineering from Lowell Technological Institute in Massachusetts. ■

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