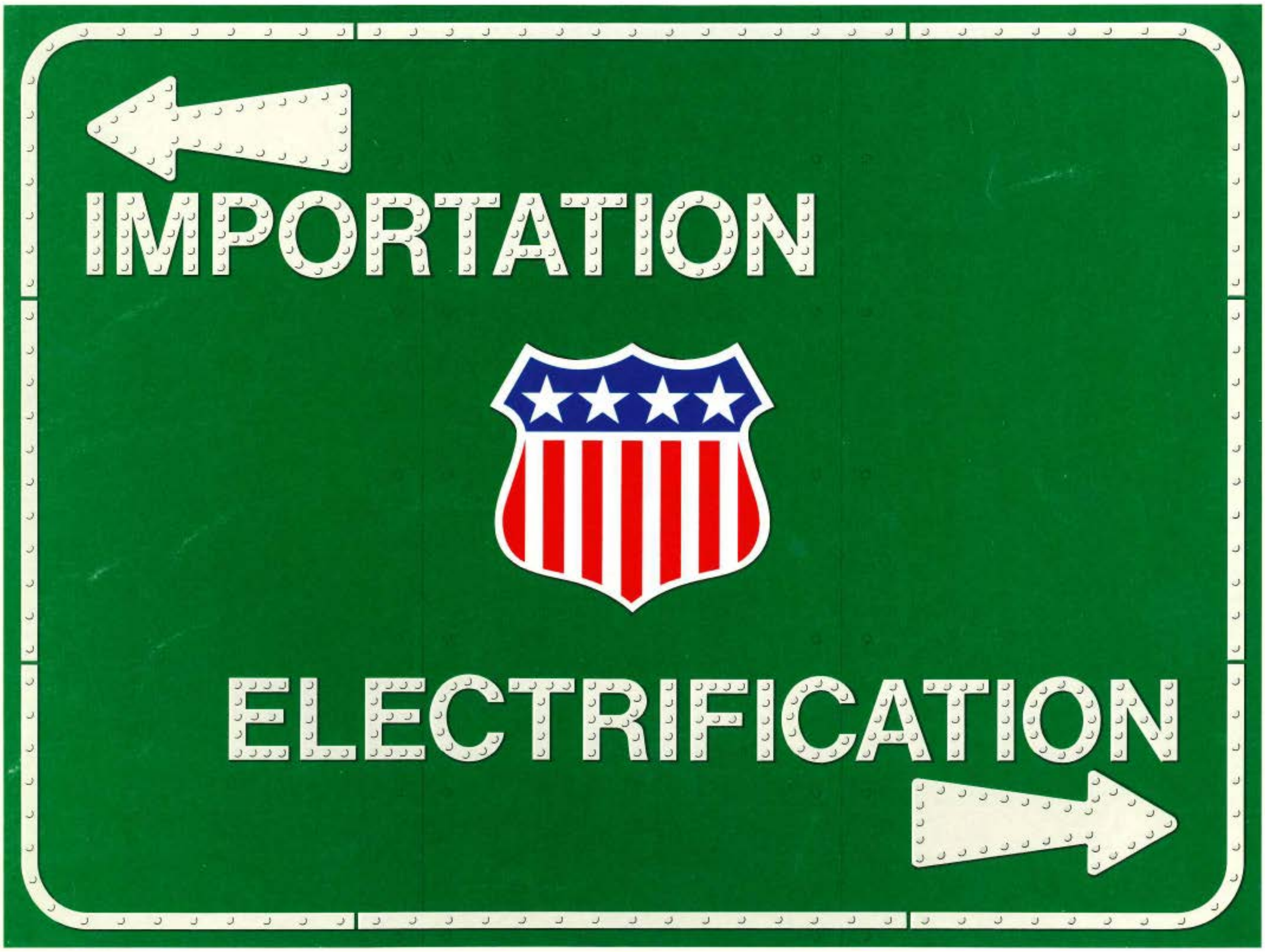
Fueling the Future

ELECTRIC POWER RESEARCH INSTITUTE

EPRI JOURNAL

MAY
1979



EPRI JOURNAL is published by the
Electric Power Research Institute.

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

EPRI JOURNAL Staff and Contributors
Brent Barker, Editor
Ralph Whitaker, Feature Editor
Nadine Lihach, Feature Writer
Jenny Hopkinson, Feature Writer
David Dietrich, Technical Editor
John Kenton, Nuclear Editor
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Marie Newman (Washington)

Graphics Consultant: Frank A. Rodriquez

Robert A. Sandberg, Director
Ray Schuster, Assistant Director
Communications Division

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

Cover: Energy forecasters perceive two major roads to the future: increasing reliance on imported oil and accelerated use of domestic resources transformed into electric power.

EPRI JOURNAL

Volume 4, Number 4 May 1979

No Facts About the Future

The national mood on energy vacillates between euphoria and depression. As additional energy resources are developed, such as the oil reserves in Mexico, or as advances in technologies are announced, such as the progress on fusion research, the answer to our energy needs seems close at hand. But as such world events as the Iranian crisis demonstrate the perilousness of our present supply, we are plunged again into deep concern for our energy future.

Underlying the need for a rational energy strategy is the need for a dependable fact base on the prospects for energy supplies and the outlook for energy demands. Unfortunately, there are no facts about the future. It is in this vacuum that the understanding about our energy future must be developed and the choices of energy alternatives must be made.

Careful analyses can sketch the alternative courses of our energy future and their assumed probabilities of occurrence. But prophecy is not fact, and all such probes into an uncertain future remain in a constant state of evolution. Underlying assumptions, subject as they are to the inertia of history and the vagaries of current events, must be continually recast in the light of new and more plausible information. Thus the long-term projections of energy supply and demand in this month's lead article show considerable variance from those of only two years ago.

The EPRI Supply Program has integrated the research done for them to date to develop insights into the production of fuels and their prices under alternative sets of assumptions. Other assumptions, of course, would result in different projections of the future. While the projections described are the base case of the program's integrated results, the forthcoming report, *Supply 79,* from which the article was drawn, describes several other possible futures.

Similarly, the projections of energy demand reflect the integrated work done to date for the Demand and Conservation Program. These forecasts are based on assumptions as to the size of the economy, the types of goods and services produced, and the factors used in producing those goods. The base case demand projections are inexorably tied to these assumptions. Different assumptions would yield comparably higher or lower demand estimates. The forthcoming report, *Demand 79,* from which the article was drawn, attempts to show clearly the premises on which the base case was built and the effects of varying those premises.

It is important to recognize that the base case may not be the appropriate projection to use in planning for the future. Prudence, for example, might dictate the use of an alternative scenario. As other EPRI studies show, there is a substantial value in the avoidance of energy shortages—minor shortages can result in mere inconvenience, but more serious shortage may lead to lost production and substantial costs for customers. Very serious and continuing shortages may risk social upheaval, pitting residential consumer against industrial user, the poor against the rich, or even nation against nation. International conflicts have often had their seeds in resource shortages, and in the last few years there have been those who have proposed violent solutions to energy shortages. It is for this reason that the projections used for planning EPRI's R&D strategies differ from those shown in the lead article. To ensure that new technologies will be ready if needed, R&D plans are based on more optimistic growth rates for the economy, resulting in more intensive energy use.

In face of the inherent uncertainty of the future, we still must plan the best we can. Whether our role is one of determining which R&D developments to support, whether an additional generating station is needed, or what price to charge for energy service, we need to understand the likely fuel markets and the expected energy demands. It is in the spirit of adding to this understanding that EPRI's Supply Program and Demand and Conservation Program present the synthesis of their latest findings.

René Malès, Director
Energy Analysis and Environment Division

Authors and Articles

Four articles in this month's *Journal* scan the energy landscape from four points of view, describing features that influence utility industry R&D. The fifth article takes a more narrow focus, reviewing a new technology that can slice into pavement with surgical precision.

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Supply and demand constitute the two sides of the U.S. energy scene. But do they match up in projections as they inevitably do in the historical record? EPRI's Milton Searl and Robert Crow direct separate, continuing studies to identify and evaluate the discrepancies that must guide R&D programming. Mary Wayne reports their latest findings in "Energy on the Horizon" (page 6).

Envisioning scenarios is not a simple task when modeled energy relationships for the future are constantly subjected to new information and altered assumptions. Correlating and interpreting the projections become acts of judgment for Searl and Crow, both of whom have headed research programs in EPRI's Energy Analysis Department since they came to the Institute—Searl in December 1973 and Crow in July 1974.

Searl, manager of the Supply Program, was a senior research associate with Resources for the Future, Inc., before he joined EPRI. Earlier he was chief economist for a division of the Atomic Energy Commission and then for the energy policy staff of the President's Office of Science and Technology. Crow, manager of the Demand and Conservation Program, was on the faculty of the school of management at the State University of New York at Buffalo. Before that, he was a regional economist with the U.S. Department of Transportation and then assistant director of economics for Mathematica, Inc.

Crow Searl

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If U.S. energy projections for only 25 years ahead are viewed as the horizon, then the historian's much longer view requires a higher vantage point. The energy landscape of centuries, marked by capabilities evolved in the past and by their implications for the future, was surveyed by speakers and participants at the Edison Centennial Symposium, cosponsored by EPRI and the Thomas Alva Edison Foundation in April. "The Open Future" (page 13) summarizes and interprets several symposium themes on energy, technology, and the human prospect.

The author is Nilo Lindgren, who, as guest editor of the March issue of the *EPRI Journal,* was deeply involved for more than a year in tracing the genealogy of electric industry R&D. Lindgren's—

and the symposium's—message from the history of technology is paradoxical: History conditions our energy decisions today; yet those decisions, in turn, create and condition the human prospect, the history yet to be written.

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Another picture of the U.S. energy landscape emerges when it is mapped in terms of utility size. The country is a patchwork of large and small organizations, with a varied topography of technological emphasis. Hidden behind the obvious peaks of big utilities and their advanced R&D needs lie smaller organizations, many of which are solely in the transmission and distribution business and have their own special problems. In "R&D for Small Utilities" (page 20), *Journal* feature writer Nadine Lihach reviews EPRI's explorations among its municipal and rural cooperative utility members.

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Seen from a quarter-inch away, a ground surface can hardly be called a landscape. But visualize a chalked or painted stripe on top of 6 inches or more of urban pavement. With increasing frequency, electric utilities are trenching along these crowded traffic ways to install underground transmission and distribution cables. The need is to get in and get out quickly, neatly, quietly, and economically. "Cutting Costs Underground" (page 24) describes how an EPRI-sponsored machine performs, using high-pressure water jets to slice out pavement sections ahead of a backhoe.

Journal feature writer Jenny Hopkinson was aided by Thomas Rodenbaugh, project manager in EPRI's Electrical Systems Division, who guided the development of this device.

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R&D management relationships germinate and grow in great variety across the energy landscape today. Among the newer ones are those between EPRI and the many U.S. utilities that serve as hosts for selected phases of Institute research. Just defining those relationships—to distinguish host utilities from their other possible roles as EPRI members, contractors, advisers, and sponsors—is a precise task.

Researching the variety of EPRI host utility projects took the *Journal*'s John Kenton on a 6000-mile nationwide trip and into more than 20 interviews. The result, "Host Utilities: EPRI's Real-World Laboratories" (page 26), reveals the purposes, incentives, criteria, procedures, problems, costs, and benefits seen by host utilities as they cooperate in testing research concepts and proving development results in the authentic context of utility system operations.

First it was the Arab oil embargo, then last year the coal strike. Now the Iranian revolution has triggered yet another fuel crunch. Will there be more such shortages? Are we doomed to a long succession of energy squeezes?

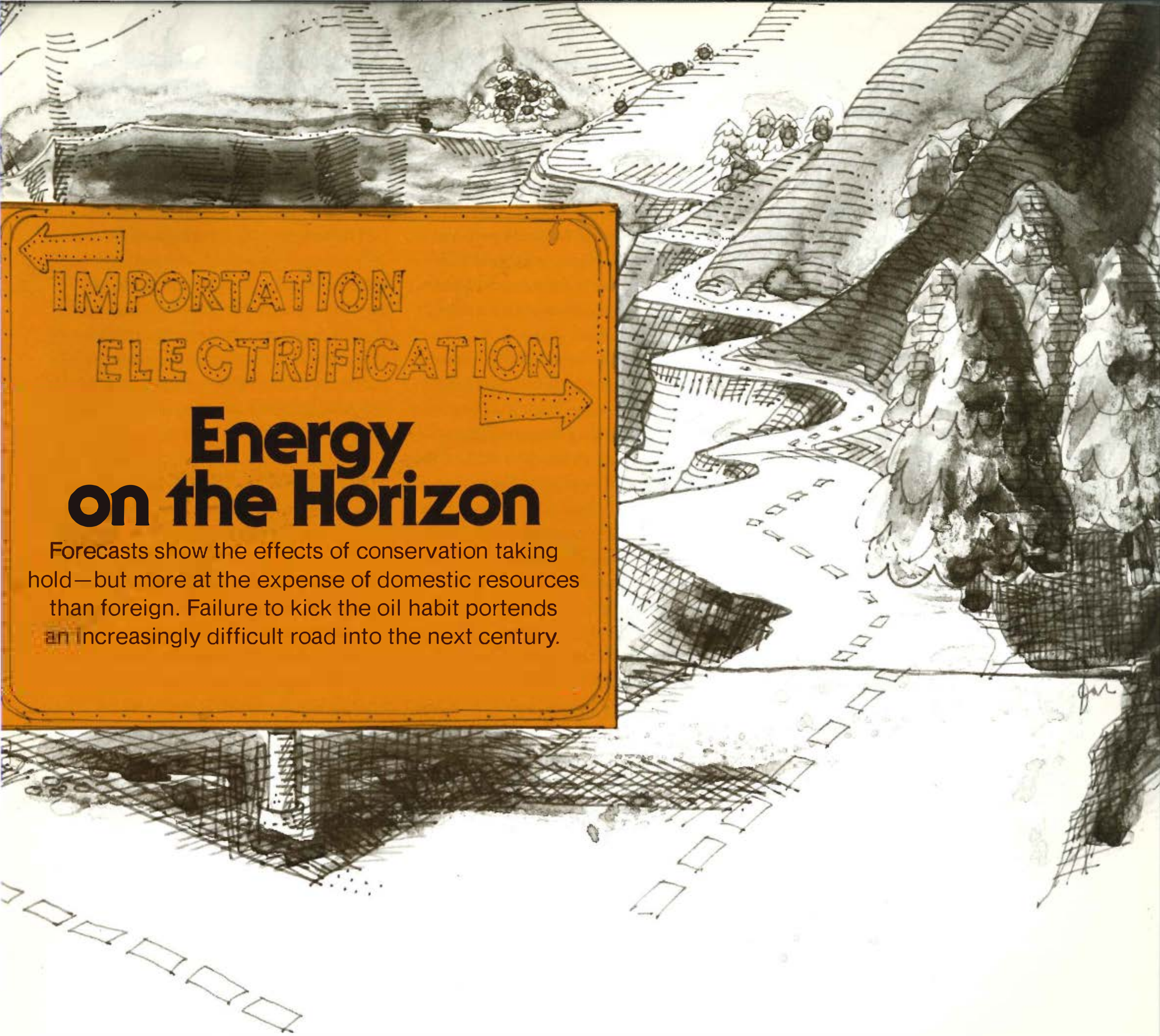
Probably so, according to EPRI forecasters' latest scan of the future. Operating on a thin energy margin means that any large demand surge or supply cutoff can cause a crunch. Although catastrophic problems do not loom on the horizon, it does appear that difficult days are ahead before a new and more stable energy balance takes shape.

Pieces of the puzzle

Matching supply with demand has turned into a tougher puzzle than preembargo energy planners ever imagined. For example, the big news on the demand side this year is that energy use is running well below what was expected a couple of years ago and will probably continue to do so. On the face of it, this looks favorable. If demand growth is slowing down, then supplying that demand should be easier than had been expected.

But things are not so simple. What if demand slows most for those fuels that are abundant, such as coal, and least for those, such as oil, that are already scarce? Far from relieving our dependence on foreign fuels, this sort of shift could intensify it. Domestic coal resources might lie idle while we forage for imports to feed our appetite for oil.

Perhaps this scenario could never de-



Energy on the Horizon

Forecasts show the effects of conservation taking hold—but more at the expense of domestic resources than foreign. Failure to kick the oil habit portends an increasingly difficult road into the next century.

velop in the face of federal policies to the contrary. But it is one possible trend suggested by the latest demand and supply projections. Though not directly comparable in format or methodology, these two forecasts reviewed together can give an idea of our prospects for a workable energy balance in the future.

Conservation trims demand

Preliminary projections from EPRI's Demand and Conservation Program, headed by Robert Crow, confirm a picture of slackening growth in energy use. The slowdown already evident this year has triggered a hefty downward revision of demand estimates for the century's end: from 1977's estimate of over 150 quadrillion (10^{15}) Btu to around 130 quadrillion Btu for total energy; and from over 7 trillion (10^{12}) kWh for electricity to around 5 trillion kWh.

Why the sag in projected total energy demand? Lower projected economic growth is part of the reason. What's more, the accelerated trend away from manufacturing and toward services augments this effect. Manufacturing eats up vast quantities of fuel and electricity, whereas the energy input in producing services is significantly less.

Perhaps even more important in explaining the demand slump is the fact that conservation will be making a far bigger dent in the nation's energy habits than was expected in 1977. Electricity prices in particular are projected to be higher than they were in the 1977 forecast. People are expected to save energy simply because it costs more, and they don't want to spend the money. This sort of price-induced conservation in homes, businesses, and industry accounts for a sizable chunk of the new energy savings.

Government policy is also playing a larger and larger role in energy cutbacks through standards, regulation, and tax incentives. The passage of many of President Carter's energy-saving proposals, even in modified form, is already making an impact on our demand outlook.

The factors that affect total energy growth projection also affect those for electricity. In addition, compared with two years ago, these projections include the expectation that more natural gas will be available, oil (including imports) will continue in sufficient supply to meet demands, government incentives to adopt cogeneration will have been legislated, and solar energy will be used in more significant amounts.

Most important, our 1977 projections of residential and commercial energy costs by the year 2000 were 20% lower than our current projections. This results in a reduction from the 1977 forecast in electricity demanded by the residential and commercial sectors. It appears that if oil and gas are available, less electricity will be used. Thus, since projected petroleum consumption is expected to be only slightly lower than the earlier projections, and natural gas considerably higher, electricity consumption is expected to be much lower.

Finally, the forecasts are based on a new model that tends to yield somewhat lower projections, given the same assumptions of economic growth, prices, and fuel availability.

Home and business savings

In the residential sector, federal energy policy calls for 90% of the nation's homes to have some insulation by 1985. Probably 70% would have ceiling insulation anyway, as a result of today's building standards. Of the remaining 20% needed to achieve the target, EPRI forecasters have assumed that 8% will be insulated in response to rising energy prices and 12% in response to federal and state tax breaks.

Ceiling insulation will pare down home demand for natural gas and heating oil by about 3% by 1985. Further efforts to weatherize will cut another 2.5% by the year 2000. These percentages may sound small, but the actual savings will equal the energy of about 190 million barrels of crude oil a year by the century's end.

A second major thrust of the federal program is to expand solar heating to 2.5 million homes by 1985. If solar could provide 50% of the energy for space heating and as much as 70% of the energy for water heating in these homes, then solar could replace 1% of total residential energy use by 1985. By the year 2000, this share could increase to 5% as the number of new homes with solar heating increases.

Switching to solar, like adding insulation, will save a lot more oil and gas than it will electricity. About 90% of the total energy savings in homes will come from reducing oil and gas use. Only 10% will come from shaving electricity demand.

The really big cuts in home electricity use are expected to come from a combination of voluntary conservation and more efficient appliances. Recent home consumption figures suggest that cost-conscious consumers are finally getting into the habit of turning off unused lights and unwatched TVs. But there is a snag. The same cost-cutting urge could also slow down the switch to electric or solar heating if imported distillate oil for home heating remains the cheaper choice.

Government regulations will make sure that home appliances work more efficiently in the future. Savings from new federal and state performance standards are forecast to carve 1.3% off residential electricity use by 1985. By the year 2000, when the appliance stock has turned over completely and everyone is using the improved models, electricity savings will climb to a more substantial 4.3%.

Of course, higher energy prices would have triggered a push for more efficient appliances anyway, even without the aid of legislation. So Demand Program forecasters have assumed that price and policy can take roughly equal credit for anticipated cutbacks in electricity use.

The commercial sector will also realize savings. With builders hewing to more rigid construction standards for new offices and stores, energy savings in the 4% range are projected by 1985. By the year 2000, total energy savings for business, counting the impact of more efficient business machines, will have climbed to 7.5%.

Shaving industrial demand

The main developments on the industrial energy horizon are three: fuel taxes, restrictions on burning oil or natural gas in new boilers, and a renewed emphasis on cogeneration.

Federal tax prods and fuel bans are aimed at shifting industrial demand from oil and gas to coal. These measures should add about 0.5% every year to the coal share between now and 2000. Starting in 1990, solar will also move in to replace 1% of industry's oil and gas consumption.

Cogeneration occurs when an industrial plant generates its own electricity, often using the excess steam as input to its main process or to satisfy heating needs. EPRI forecasts estimate that cogeneration will take up annual increments of 1% of purchased industrial electricity until the year 2000. Because most cogenerators favor oil and gas as fuels, though, this method of reducing purchased electricity can actually increase oil and gas consumption.

So the cloud on the conservation horizon is that electricity savings may come at the cost of increased reliance on fuel imports.

Changing auto use

Federal policy is bearing down hard on gasoline use. The proposed gasoline tax seems to have evaporated, but spiraling pump prices will pack much the same wallop. With Energy Secretary Schlesinger predicting $1 a gallon for unleaded gasoline in less than 18 months—and the prospect of "white market" rationing coupons costing the profligate motorist an extra $1.25 or so per gallon for excess consumption—many people will think twice before driving more than necessary.

When and if electric cars begin rolling off the assembly line, they too are expected to boost the conservation trend. Electric vehicles are forecast to save 1% of the petroleum used for transportation by 1985, followed by 2% in 1990, 4% in 1995, and 6% in the year 2000. Given the fact that transportation is and will remain our major consumer of foreign oil, such savings are by no means trivial.

How much energy?

Taking all conservation into account, how much energy will we still need? How fast is energy demand expected to grow? And to what level?

The implication of this scenario is to drop the growth rate for total energy demand between now and the year 2000 to well below the historic growth rate of 3.3%, although higher than the 2% limit targeted by federal conservation planners.

Fossil fuel use will grow at different rates. Coal use, for example, will about triple over its 1976 level by the year 2000. Oil use, substantially dependent on imports, will nearly double. Natural gas consumption will climb less than either coal or oil, but even gas will expand slightly over its 1976 level by the century's end. All these figures for fossil fuels rest on the assumption that nuclear power will keep growing, though not so rapidly as predicted in the past.

Electricity use will continue to rise faster than total energy use. But if gas and oil are available in the quantities predicted, the difference will not be as great as once expected. Electricity's share of total energy by the end of this century is now seen at only 35–40% in this scenario, a substantial drop from the 47% forecast earlier.

While forecast electricity growth is down in both home and industrial use, projected oil consumption is roughly the same as in earlier forecasts. This is not a happy prospect in terms of the national drive to switch our energy base from oil to coal. Coal needs for electricity production can be met domestically, whereas increasing oil use inevitably points toward increasing imports.

There are growing indications, however, that such increases may be unacceptable as a matter of public policy. Limiting imports would tend to shift consumption to direct use of coal, electricity, and new forms of energy production such as solar. Little shifting toward natural gas is likely, since it is predicted to be limited by supply. If oil imports are limited and domestic oil production is lower than forecast, and if gas is less available than expected, the demand for electricity could be substantially higher than in this scenario.

Supply: bumping the limits

The EPRI Supply Program, headed by Milton Searl, sees adequate energy supplies ahead—as long as the imported fuels keep flowing. But this does not mean that supplies will be adequate at every time and place. The current oil squeeze is typical of the intermittent shortages that will occur as we learn to live on a stricter energy diet.

Historically, Americans have relied on our excess production capacity and imports to cope with sudden demand surges or supply cutoffs. Now that cushion is gone. As Searl points out, we must now expect to "keep bumping supply limits from time to time."

The only way to avoid these bumps is for the government to stash away a very substantial fuel reserve or for private producers to build up excess capacity. Either course could be costly but might be less expensive than the effects of bumping against energy limits. And for either course, the public would foot the bill, as taxpayers or as consumers. Since the public today seems to be in no mood for increased spending, more frequent minor collisions with supply limits seem unavoidable.

Using both domestic and imported fuels, current technologies will meet most of our needs between now and the year 2000. After the turn of the century, emerging technologies will assume a greater share, so supply forecasts have now been extended to the year 2030. Here's the forecast for domestic production by individual energy sources.

Oil production

Domestic oil production is finally on the rise. The long decline has bottomed out during the past year and supplies have begun to swell, despite some disappointments at the fairly meager discoveries from new offshore drilling. With Alaskan oil now flowing, the forecast is for gradually increasing production from domestic petroleum resources for the rest of this centry. Oil production, which stood at 10 million barrels per day in 1975, is expected to peak at 12–14 million barrels per day by the year 2000.

Soaring domestic oil prices have stimulated production, making it worthwhile to go after deposits that would have been too costly to develop at lower price levels. Even the difficulties of extracting oil from shale look less formidable to oil producers, who have higher prices to spur them on, although environmental problems persist.

Supply Program forecasts for the near term see domestic crude oil prices continuing their rapid ascent. They are predicted to climb swiftly from $10.45 in the first half of 1978 to over $14 (1978 $) in 1980, close to the world oil price, and then follow world oil prices upward.

What to do with these ballooning oil revenues is a controversial policy issue. Should they go to fund exploration for oil and gas? To support R&D on advanced energy options? To lighten the burden of rising energy costs on low-income consumers?

Whatever the price and policy outcomes, the role of domestic oil as an energy source will eventually decline. We will keep pumping oil in large amounts for the rest of this century, but by 2030 oil is forecast to account for only 18% of our domestic energy production, in contrast with about 33% today.

Natural gas supplies

Natural gas, now in the midst of a brief surplus, will show a similar production pattern over the next several decades. Starting from a level of 19.2 trillion (10^{12}) cubic feet in 1975, conventional natural gas production is expected to swell to around 23 trillion cubic feet in 1990 and then fall back to 20 trillion cubic feet by the year 2000.

The uncertain fate of natural gas prices is in the hands of government regulators. While natural gas prices will increase substantially, price categories are so complex that predicting average prices requires many assumptions. To arrive at the output levels projected here, EPRI forecasters have assumed that average wellhead prices *will nearly quadruple by the year 2000.*

If prices rise even higher, they will temporarily buoy gas production above the levels now forecast. But this will only delay the eventual decline of conventional natural gas as an energy source. Where fuels in gaseous form are still needed, the long-term prospects are for increased reliance on imports and/or a switch to gas from unconventional sources (for example, coal conversion, bioconversion, and geopressure zones).

Conventional natural gas, which accounted for about 32% of our domestic energy production in 1975, is expected to account for only 3% in the year 2030.

Coal outlook

Coal forecasts to 1985 have not changed much during the past year, despite the prolonged coal strike and the ensuing wage settlement.

Coal output is, in fact, still swelling, but coal producers are disappointed that the long-term demand levels now foreseen are not as great as previously expected. For one thing, about two-thirds of all domestic coal is fed into power plant boilers. With the demand for electricity now falling well below earlier forecasts, new coal production estimates must reflect this sag.

When electricity demand was projected to soar to about 7 trillion (10^{12}) kWh by the year 2000, coal supplies were slated to hit 2.6 trillion tons. Now that electricity demand forecasts have been revised downward, coal production is expected to fall well short of 2000 million tons. Coal supplied 26% of our domestic energy in 1975. It is now expected to supply 35% in the year 2000, down from 1977's more expansive estimate of 46%.

Unless the outlook for electricity growth improves, coal may never, in fact, reach that lofty percentage. And unless clean fuels from coal can be made available sooner and at lower cost than now anticipated, new power sources will make increasing inroads into coal's market, whittling its share of domestic production back to about 30% by 2030.

The other big "if" in the coal picture is the future of nuclear power. Nuclear and coal-fired capacity have been assumed to develop in tandem, carrying roughly equal weight in our generating mix by the year 2000. If, instead, nuclear power falls far below even the reduced growth estimates given in the next section, then coal output must soar in an effort to fill the supply gap.

Nuclear power

Forecasts of nuclear power growth are down, and quite substantially so. Last year's forecast of a 380-GW nuclear capacity by the year 2000 has been chopped to 256 GW—nearly a 35% drop, although still almost five times the 1978 level.

Part of the reason is the same as for coal. Electricity demand is not growing as fast as expected, and the market for commercial nuclear power is firmly linked to electricity demand.

But there is also another reason, and that is continuing opposition to the growth of nuclear power. Previous forecasts were based on two assumptions: that the rate of orders for new plants would increase, and that the time required to get them on-line would decrease. Neither of these assumptions has worked out so far.

Only 2 new reactors were ordered and 5 existing orders were canceled in 1978 from an industry with the ability to produce 20 or 30 a year. On top of all this, the events at the Three Mile Island facility and subsequent calls for a nuclear moratorium must further depress the prospects for conventional nuclear power growth during this century.

Looking ahead to the next century, Supply Program forecasts become more positive. The prediction is that the United States, when faced with looming power shortages and loss of leadership in the nuclear field, will finally relent and take its breeder program off the shelf. If this happens soon enough, the breeder could help furnish a substantial chunk of our energy supplies by the year 2030.

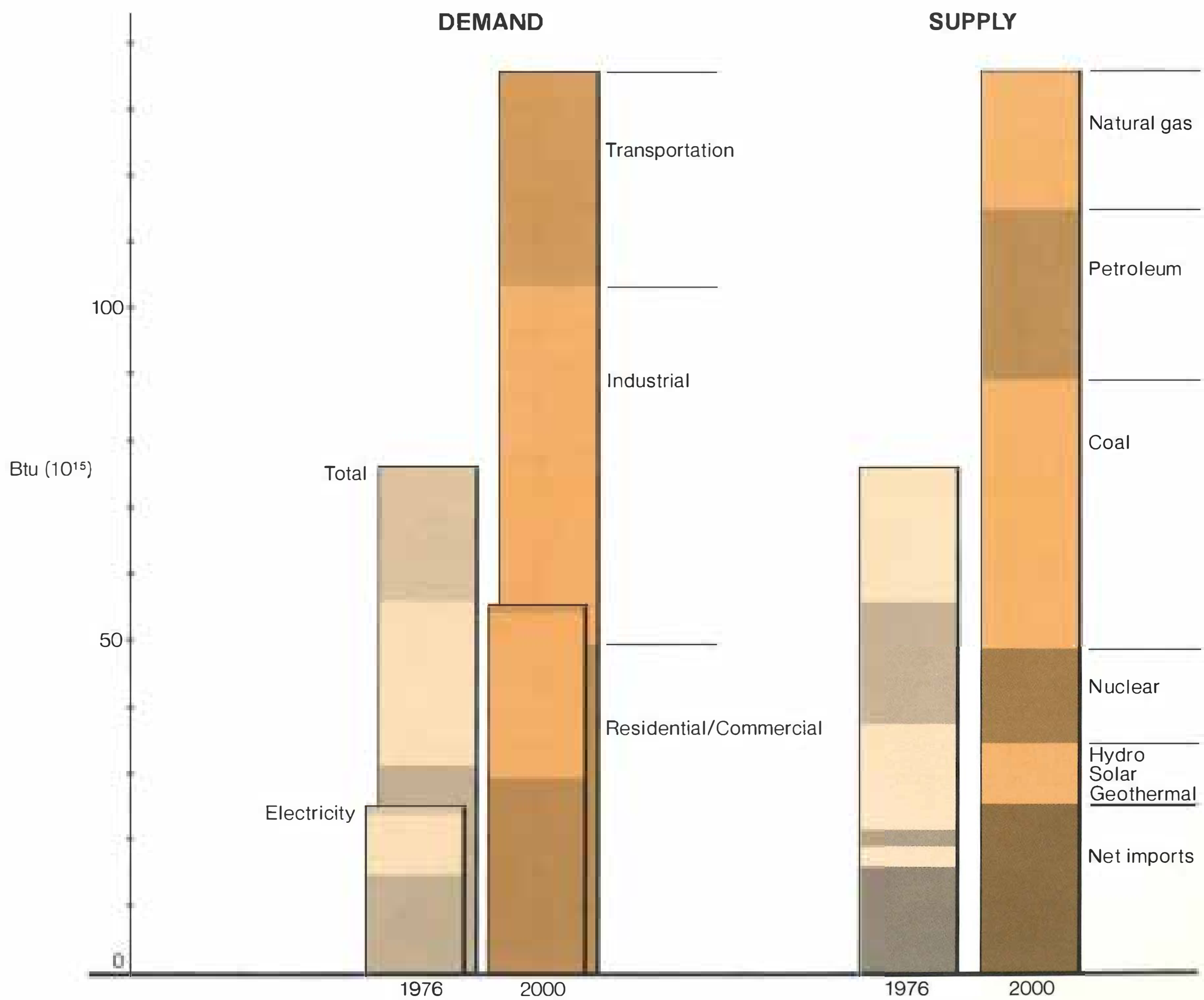
Hydroelectric production

Hydropower, favored as a clean and economical energy source, is expected to expand only modestly over the next two decades. From the energy equivalent of 160 million tons of coal in 1975, hydro is forecast to equal 200 million tons by the year 2000. This represents some growth in absolute terms, but a declining share of energy production.

Hydro's share seems destined to shrink for one simple reason: the number of suitable sites is limited. Hydro, which supplied just over 5% of our total energy needs in 1975, is expected to provide no more than about 3% by the year 2000. And that share will probably fall even further by 2030 because most available sites will have been fully developed.

New energy sources

The need to understand the role of new energy sources is the main spur for extending EPRI supply forecasts to the year 2030. During this century, the role of alternative technologies is expected to remain very small. All of them put together will provide only about 5% of our domestic energy supplies. By 2030, how-



EPRI forecasts U.S. energy demand will reach approximately 130 quadrillion (10^{15}) Btu by the the year 2000, with coal and nuclear—delivered in the form of electric power—assuming an increasing role. As presently foreseen, the supply gap will have to be filled by imported energy.

ever, that figure could grow to about 25%.

Solar and geothermal will probably be the first to make a discernible dent in our energy needs. Each will contribute 1–2% to the year 2000 energy mix. Wind power, fuel cells, and the burning of waste/biomass fuels will also make small contributions.

By 2010, the long-delayed breeder reactor is expected to be on-line. And by 2020 the scenario includes some power sources that are considerably further away from what is technologically feasible today: possibly photovoltaic cells generating electricity from sunlight; solar satellites hovering in space, receiving energy from the sun and beaming it to earth; and maybe even fusion reactors creating power from the deuterium found in ordinary water.

All told, the breeder and these new sources could generate as much as one-third of our electricity by 2030. The rest will likely come from continuing use of the two main sources already established during this century: coal and conventional nuclear fission reactors.

Electricity production

Increasing electricity output by two and a half times by the year 2000 is forecast to hit no insurmountable roadblocks. It will be a constant challenge, however, to achieve this capacity.

If continuing problems with nuclear power cramp the growth of that energy source, then over the long term, electricity input needs could, in theory, be met in other ways. Domestic coal, for example, probably could be expanded sufficiently to take up the slack *if* the switch is not too sudden and *if* the expansion is permitted by regulation. Otherwise, the indicators point to renewed use of oil and gas imports in power plant boilers, which seems unlikely from a policy point of view. More rapid growth of electricity demand, however, would be extremely difficult to satisfy without full use of both coal and nuclear resources.

An analogous situation applies after the year 2000. If the breeder is allowed to make its contribution to U.S. electricity generation in the twenty-first century, then electricity can continue to grow without resource constraints. Should the breeder stay on the shelf, however, we could begin to feel a pinch on domestic uranium supplies. And the answer, once again, would be imports, if allowed by policy.

Electricity prices will keep rising, though not so fast as in the recent past. Part of this increase will come from higher fuel prices for coal, as well as for oil and gas. Meanwhile, the capital costs of new capacity will keep expanding. And the slice of utility revenues tagged to meet environmental costs will probably keep getting fatter.

Electricity that cost 3.5 cents per kilowatthour in 1975 is forecast to cost 4.1 cents in 1985 and 4.5 cents by the year 2000 (1978 $). This is a major reason that electricity use will probably not grow as fast as once believed. Other energy sources, notably oil, will be cheaper for certain purposes, especially during the decade just ahead.

Imports creep upward

Taking these demand and supply forecasts together, what's the outlook? Can domestic supplies meet a greater share of our needs in the future? Can we cut down on fuel imports?

Not anytime soon, unfortunately. Even though demand growth is slowing, even though conservation is trimming energy use more than expected, the nation will not be able to supply all its own energy needs by the year 2000. We will still be importing oil and gas for the rest of this century, and uranium imports could be important in the next.

Domestic energy production is forecast to total over 100 quadrillion (10^{15}) Btu in the year 2000. This figure falls about 30 quadrillion Btu below forecast demand. So the supply gap will have to be filled with imports. If the forecast trends hold, this means that Americans who relied on imported energy to meet 16% of their needs in 1975 will be importing over 20% of their energy by the century's end.

Especially troublesome is the prospect of expanding oil imports. The national trend toward substitution of coal-based electricity for oil seems to be bogging down. And this is clearly bad news from the standpoint of achieving energy self-sufficiency and strengthening our balance of payments.

Fortunately, there is also some good news. An increasing portion of our fuel imports may come from our immediate neighbors, Mexico and Canada. As President Carter learned on his recent Mexican visit, this is no guarantee of bargains. But it does give us some measure of security against fuel cutoffs.

The economies of the North American nations are firmly interwoven. Mexico, in particular, depends heavily on U.S. food exports to feed its growing population. Crippling the United States with an energy embargo would clearly not serve their own best interests.

A new balance

A new energy balance seems to be taking shape in the United States. This balance will still rely on imports, but we may be able to diminish our vulnerability to decisions and events occurring halfway around the world.

Higher price levels will also be part of restoring our energy equilibrium. They will help by boosting production and discouraging consumption. Over the long run, the soaring prices that are creating such confusion in energy markets today will stabilize the balance between energy demand and supply.

Will we have energy enough in the year 2000? This set of EPRI forecasts say that we will—in the year 2000 and beyond. But our new energy diet, though adequate, will be spartan by the standards of our earlier abundance.

Periodic crunches will occur. The dream of providing for all our needs from domestic resources will not come true during this century. And we will never again have energy at the bargain prices of the past.

The struggles going on in society today, which find expression in many polarized forms, seem to be operating within the framework of a relatively new perception of the world as having finite limits: finite resources, finite capital, finite energy, finite capability for sustaining life. With the disappearance of the last external frontier, people seem to be grappling with the frontiers within, the reach of the human spirit, its adaptability and creativity, which may or may not be finite. It should not be surprising, then, that the struggles over the reach and consequences of science and technology—man's most stupendous tools of all time—should turn into struggles over human values.

These were but a few of the themes explored during the three-day symposium in early April, "Science, Technology

Report on the Edison Centennial Symposium
San Francisco, April 1–4, 1979

The Open Future

Whether man controls his most stupendous tools—those created by science and technology—and whether he can continue working and living in a finite world as though it were infinite were some of the issues debated during the symposium. At the core, however, was the sense that our future remains as open as always.

and the Human Prospect," sponsored by EPRI and the Thomas Alva Edison Foundation. The symposium, held in San Francisco, commemorated the centennial of Edison's invention of the incandescent lighting system by bringing together 700 scientists, humanists, industrialists, philosophers, academicians, and students to weigh the potential role of science and technology in man's future welfare.

In general, the symposium was a balanced, hardworking conference, with a minimum of speechifying at one another and a consistent level of open-mindedness to find the best ways of coming to grips with seemingly intractable questions. Overall, the often unconscious arrogance and routine optimism that mark many scientific and technological conferences were muted in this one. Scholarly intellectuals and pragmatic utility representatives rubbed elbows and wondered openly about the outlooks of each other. The sobriety of the symposium themes—humanity struggling with its own destiny, attempting to comprehend the potential scope of its scientific and technological tools in their "good" and "bad" effects—sounded the predominant chords.

The growth of limits

Opening the symposium were three challenges by Chauncey Starr, George Basalla, and Philip Morrison; each in its own way invited an enlarged perception of the relation of science and technology to mankind's destiny.

As keynote speaker, Symposium Chairman Chauncey Starr set a deliberate counterpoint to an issue that has worried observers of western industrial growth since the publication of "The Limits to Growth" by the Club of Rome in 1972. It is really the other way around, Dr. Starr implied by the title, "The Growth of Limits." History supports the view, argued Starr, that "science and technology have continually relieved the limitations on man's ability to live in the circumstances provided by nature." Despite current apprehensions about their deleterious consequences, he confidently asserted that "these arts can continue to do so."

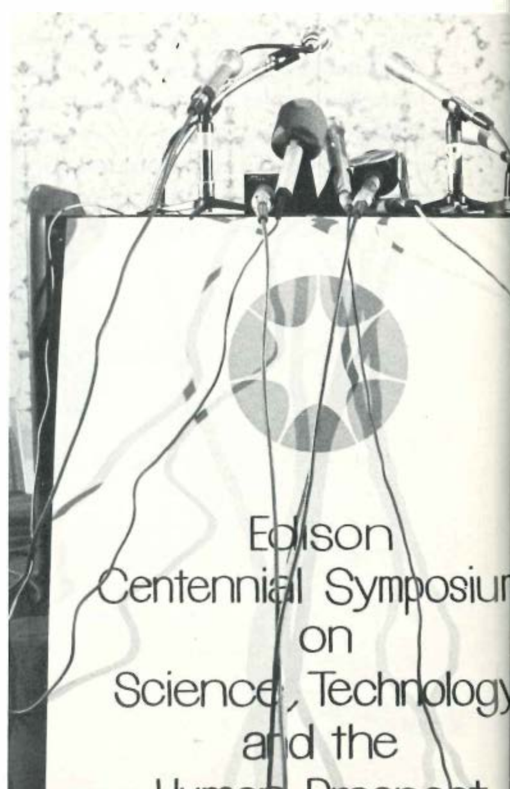
Taking as his target the doomsday syndrome, Starr continued: "I do not accept the premise that constraints on such growth are in view or that our long-range planning horizons should be determined by today's perceptions of existing limits. I believe that a long future of expanding expectations continues to be an available option if we take advantage of the fact that technology is an unlimited resource of the human mind."

According to Starr, the real question being faced today is this: "Do we want to accept the idea of limits as a guide to human expectations and societal planning or do we want to keep alive the idea of expanding expectations and new horizons? If we choose expansion, we need more science and technology applied to a spectrum of uses—some old, some new—and to the problems of dealing with the undesirable side effects of growth."

Does energy equal civilization?

Given the current fears of some form of Armageddon overcoming the industrialized world in the event of drastic energy shortages, perhaps one of the most interesting and possibly fruitful distinctions about the relations of energy and society

"Science, Technology, and the Human Prospect" was the thematic challenge that drew 700 participants from industry, government, and academia—from the U.S. and abroad.



was put forward by George Basalla, associate professor of the history of science and technology at the University of Delaware. Basalla's approach was to try to jar loose the current tight coupling that people make between energy and civilized life. People tend to behave, he argued, as if a 100% increase in energy consumption means a 100% increase in civilization, a preposterous concept when one looks at it closely. After all, the Elizabethans and the ancient Greeks, for instance, achieved high cultures without oil or steam engines. Yet the belief that the level of energy predicates the level of the civilization (what Basalla called the "energy-civilization equation") has "pervaded western thought for the past two centuries."

In tracing the history of this concept in western thought, especially to its origins in the scientific revolution of the seventeenth century, which created a new world view, Basalla identified a strong ideological component in it that he regards as both worthless and dangerous, as well as counterproductive of current efforts to conserve energy.

"Most current commentary on the energy problem," he noted, "lays stress upon available resources, economic factors, and political implications. Granted the importance of these three elements, they cannot account for all facets of the problem." Current approaches to the energy problem, he argued, ignore the fact of this ideological component that equates high energy consumption with the idea of civilization itself. Because this is so, he argued further, proposed or perceived change in energy use carries wider implications for people than living in less comfortable houses or driving smaller cars less frequently and more slowly. "As less energy is available per capita, the nation is thought to lose its standing among the world's civilizations." One consequence of this ideological assumption: "Those countries with high rates of energy consumption are ideologically committed to maintaining them, and those with lower rates are motivated to copy their energy-hungry, 'civilized' superiors.

"In the final analysis, it is important that you recognize the equation as a pervasive, if often implicit, element in both popular and sophisticated approaches to energy and society. If the equation is as worthless and potentially dangerous as I think it is, then it should be exposed and discarded because it supplies a supposedly scientific argument against our efforts to adopt a style of living based upon lower levels of energy consumption. If it is a generalization of great truth and intellectual worth, then it deserves a more refined handling than it has received from its supporters to date."

A gulf of dangers

A still wider horizon, one that has been steadily evolving over the past few centuries, was broached by Professor Philip Morrison of MIT, who energetically and sometimes passionately reminded his listeners of the gradual change that science has brought to man's perceptions of himself and his world. This second kind of light, the insight of science, he argued, is even more important than physical light inasmuch as it has "recolored our mentality."

Thus, voicing what is now perhaps the

classic viewpoint of science, Morrison steered his way toward the heart of a current problem and a modern danger: not all human cultures or all individuals share this scientific insight as a common "subsoil of the mind." This great gulf between those who apprehend science and technology and those who do not needs to be narrowed, preferably by "more light, especially of the second kind."

Energy: the "pathfinder problem"

Some sense of the problems mankind may face in its future began to surface during the parallel workshop sessions of the first afternoon. Divided along traditional lines—history; medicine and public health; food and agriculture; urban development; communications; energy; human population and ecology; science, technology, and human values—the eight individual sessions nonetheless manifested the same underlying issues and problems: No matter how you slice it, it comes down to the same point . . . tough going ahead. There may even be a critical path that mankind may need to follow to make it safely through a great transition period that many projections indicate could lie somewhere around the turn of the century. In this respect, the designation of the energy question by Wolf Häfele, chairman of the workshop on energy, as the "pathfinder problem" for the more general problem of the symposium was instructively prescient.

Drawing on an enormous body of information and insight that has been developed under his leadership of a global energy analysis at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria, Häfele laid out the structure and parameters of two scenarios for total world energy demand until the year 2030. Some of the uniqueness of the IIASA study, which has been under way for the past five years, lies not only in its incredibly detailed and interlocking analyses (regarded as the most sophisticated being undertaken by any institution) but also in its total global view. This perception is based on information coming from many nations and global regions, including the eastern planned economies, such as that of the Soviet Union, information that other groups have not had access to.

By taking a global view, Häfele said, the picture of future energy needs in conjunction with human aspirations is substantially different from those that emerge from national and local energy patterns. "In the long run," said Häfele, "major energy transitions can be foreseen, transitions that will compel society to choose between continued depletion of finite resources and investments calculated to provide a permanently available 'interest' energy income."

These transitions point to the strong possibility of major changes in societal investments in energy systems around the turn of the century from what is regarded as a disequilibrium today to a new dynamic equilibrium in the future, when societies will be putting relatively more of their capital and resources into energy systems. Beyond that could be an "age of substitutability and of new materials" and a new dynamic equilibrium of economic growth and resource availability.

Another unique feature of the IIASA study is that it has attempted to look be-

Sessions featured more than 40 speakers and 8 concurrent workshops on energy; human population and ecology; communications; history; food and agriculture; medicine and public health; urban development; and science, technology, and human values.

yond the transition period, to develop the most likely scenarios of how things might be in 2030, and then to look back to the ways in which the transition itself might be facilitated or to how critical the passage might be.

Even armed with such scenarios, the specifics of how things might be done—whether the world will muddle through or will exercise some intelligent guidance of the process—Häfele suggested, rests "with the willingness and capabilities of societies to facilitate such transitions.

"It must be recognized," urged Häfele, "that the energy problem is primarily a problem of perception extending well beyond the domain of scientific objectivity. Every individual or society has a certain perception of reality and that means, among other things, a perception of the energy problem. The uses of energy are deeply embedded in our personal lives and in the lives of societies, and therefore the energy problem most often refers to that very fact and to the way in which it is perceived."

Although the specifics of the IIASA scenarios can hardly be touched here (they point to a moderate, realistic, sustainable growth rate of 3% per year for the world, with accompanying energy demands, as opposed to much higher and lower projections of other groups) the real outcomes may depend on which schools of thought prevail within different societies. Whereas one school expects continued high growth rates, another school, noted Häfele, "wants to use the energy problem as a vehicle for their desired change of lifestyle." For instance, a line of thought represented in the workshop discussions calls for a break with current urbanization and industrial trends, for decentralization, for the invention of radical new modes of development, for more radical changes in lifestyles that could lead to much lower future energy use than projected in the high-energy scenarios, or even in the moderate scenarios, like those of IIASA. Such decentralization, representing the "soft path" in contrast to the continuation of present trends, the "hard path," calls for a strong decoupling of energy and economy and for a simultaneous movement toward the use of renewable energy sources, such as solar, wind, biomass, and hydropower. Such arguments represent another pole around which social and political forces are cohering.

In response to comments from workshop participants that the path to the future seemed gloomy indeed, Häfele observed that was not necessarily the feeling one should carry away. Rather, "The future is open, as it has always been." In effect, he said, we must do the best we can to foresee, but also to expect the unexpected.

In another of the parallel workshops, "Science, Technology, and Human Values," a workshop participant took up the theme that there seems to be a tension between science and technology on the one hand and human values on the other. But the underlying note was that we must get in touch with higher human values that will enable us to use science and technology more wisely and responsibly. "It may be hard to do, but it's our job." The response was that science and technology are not in control—people must choose and manage it. In short, "*We* [humans] are responsible, and *we* must act!"

Industry and energy: moral dimensions

Opening up yet another dimension of the tasks that the energy problem imposes on society, Alasdair MacIntyre, professor of philosophy and political science at Boston University, specifically enjoined the leaders of the electric power industry in the United States to exercise an enlarged sense of moral responsibility to the whole society. Far from being a sermon, MacIntyre's call to the industry to take on the moral task of educating our society in how to make certain types of important energy choices was charged with pragmatic, economic, and institutional reasons for what the industry could and should do, why it was uniquely fitted for the task, how other mechanisms (e.g., market and government) were inadequate, and he sketched a clear picture of the dangers the industry would encounter in heeding his call.

Citing the generally good moral record of the industry, MacIntyre nonetheless described it as a negative morality in the sense that the industry had faithfully complied with the law and the will of Congress on the one hand and with contracts and the will of the consumer on the other—"a strict morality of nonintervention in every area but that which it and others regarded as its own legitimate realm." That is, in the past it practiced a morality of constraints, albeit exercised within the basic assumption that the providing of electric power was an unqualified good (environmental concerns, and such, not having yet emerged).

But given today's problems and debates, given the counterproductiveness of the obsessive scapegoatism and polarizations that characterizes these debates, and given the failure of the government or the marketplace to provide an adequate forum, more is needed. "For the debate on energy," said MacIntyre, "is peculiarly concerned with the future; it is, in fact, a debate about investment."

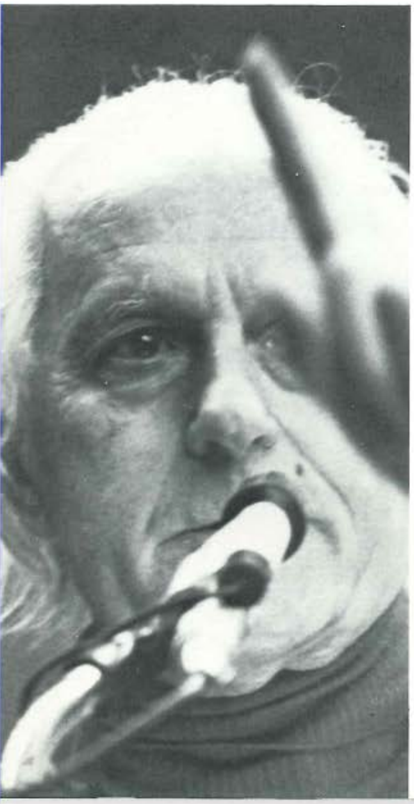
Who is to establish the necessary debate to supplement conventional economic and political institutions? MacIntyre's answer: "I see very few individuals or institutions that are capable of taking up this task and possess the resources and the strategic position to carry it through, apart from those individuals and institutions who compose the electric power industry. Their work compels them to interact with both producers and consumers at essential points. They have a peculiar responsibility, which arises from the fact that if they do not discharge it, it is unlikely anyone else will."

MacIntyre's formulation of the task and its moral dimensions is cogent. "What we now have to debate is what we are prepared to pay for what and to whom and how we are going to pay for it. The major possibility that we confront is a gigantic shift in patterns of investment. And if we invest massively in new energy sources or in new ways and to new extents in existing sources, then we shall necessarily be shifting our investment away from something else important in our lives. Hence, the energy crisis is about our whole way of life and not just about energy."

Food and famine: the other pole

An even greater task of world dimensions, in which food and famine ("the disgrace of our era") are at the center but with which energy is inextricably con-

Conclusions drawn from the symposium were as varied as the speakers; there were admonitions, prescriptions, moral judgments. If there was a consensus it was that our future lies somewhere between apocalypse and utopia—that we indeed face an open future.



nected, was depicted by René Dumont, in the workshop on food and agriculture. "It might be thought," wrote Dumont, retired professor from the National Institute of Agronomy in Paris and a longtime veteran of agricultural problems in the developing, industrialized, and socialist countries, "that the era of universal abundance had arrived and that the specter of famine, which has always haunted mankind, was about to disappear forever. Nothing of the kind!"

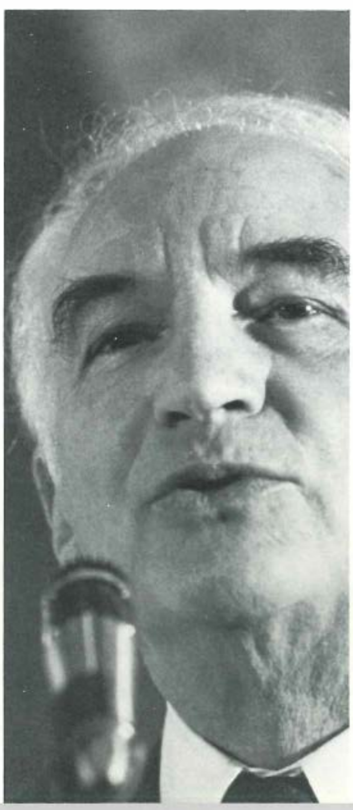
The world situation is worse today, Dumont asserted, as he laid out some of the aggravating factors, as well as a new role for science and technology. As much as anything, Dumont's outlook was the antipode of that which opened the symposium.

His position, said Dumont, was not hostile to science, rather to the current "disorganized application of science that affords extravagant privileges for the powerful." The ecologists, Dumont noted, are starting to work out a new social, economic, and political framework for survival, and he predicted that once scientists understand the consequences of current directions, their "duty is to take an active part in the debate." With all their strength, he urged, the scientists must "enter the field of politics so as to bring a halt to the race towards disaster."

Social achievements: the pluses and minuses

In weighing the effects of science and technology on individual lives and on our social and political institutions, Philip Handler, president of the National Academy of Sciences, provided an even-handed though sobering climax to the general thrust of the symposium. Noting at length the mitigations that science and technology had provided in the lives of individuals, Handler concluded that the benefits in this respect were not debatable, but the problems that had come to view and were besetting our social and political institutions were another matter. He observed that improving these and healing the radical new cleavages that have become apparent in American society would not be easy. In effect, he said, the scientists in the earlier decades had not been foresighted enough to make a greater effort to educate the general public on the risks and benefits and the potential consequences of their work. Clearly, the incident at Three Mile Island in Harrisburg was still ringing in everyone's ears. And like others at the symposium, Handler noted that today's arguments about the safety of our energy systems "are arguments about the nature of society itself."

At the center of Handler's concerns was the impact of these trends on the continuing pursuit of science. He noted particularly that when science must inform public policy—as it now must do in so many areas, such as the effect of pollution—the need for scientific rigor is even greater than in other contexts. This places a heavy onus on science. "What we [scientists] must do," he concluded, "is to admit openly the magnitude of our own uncertainties so that the political process, where science and technology are concerned, can regain confidence. In the painful dilemmas now facing society and in face of the pressures that will be applied to science and technology, we must not lose our nerve." ■

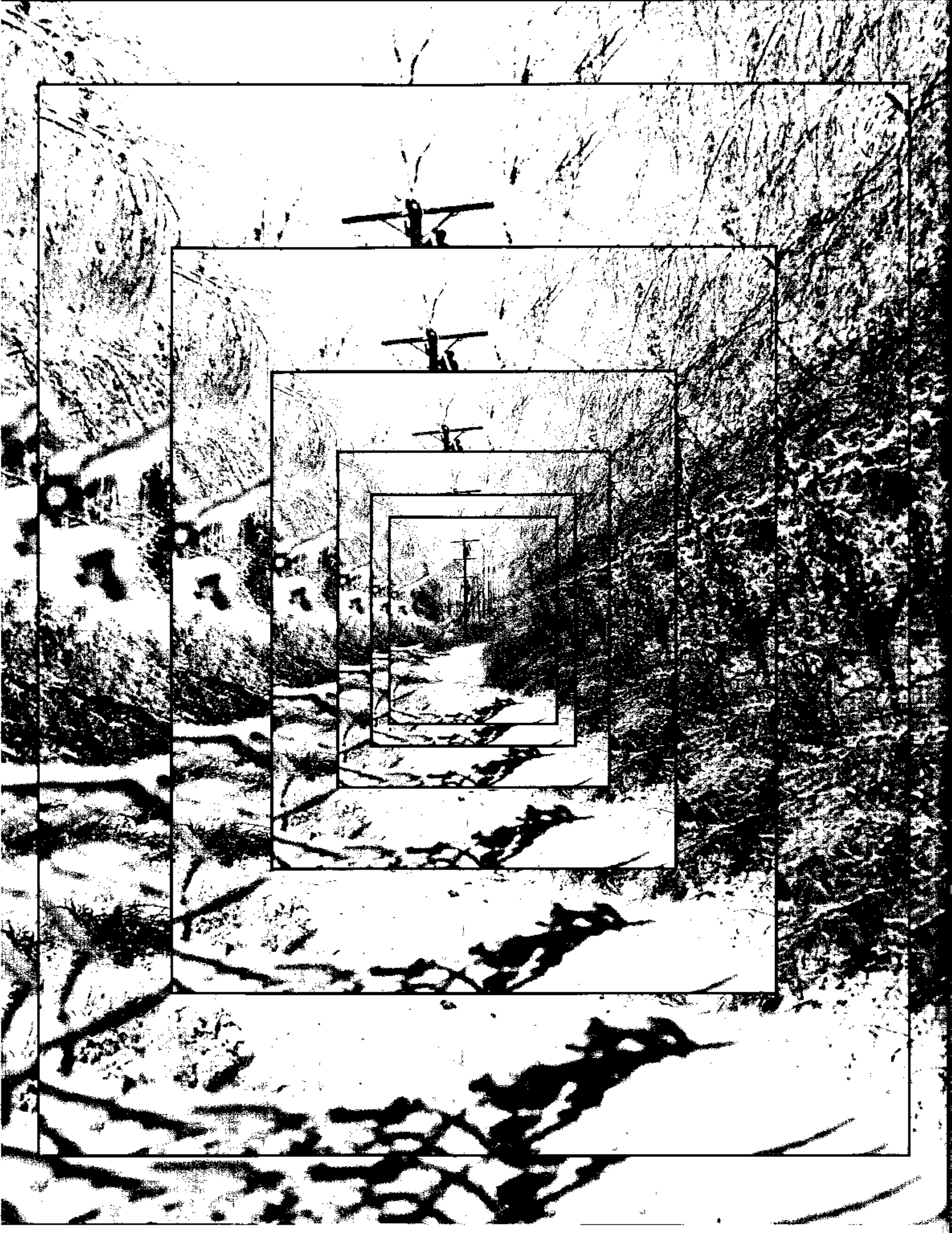


SYMPOSIUM PROCEEDINGS

The symposium proceedings will be published in hardbound form by Pergamon Press, with Chauncey Starr as editor and Philip Ritterbush as coordinating editor. The published document should be available by mid-September.

Pergamon Press is offering a prepublication price of $50 for orders received by August 31, 1979. After that date the price will be $60.

Inquiries about the proceedings should be directed to Pergamon Press, Headington Hill Hall, Oxford OX3 OBW, England; or Fairview Park, Elmsford, New York 10523 (914-592-7700).



R&D for Small Utilities

Suggestions offered by participants at a recent EPRI workshop for small utilities point up some special R&D concerns.

In America there are electric utilities that are more directly concerned with woodpeckers, ice storms, and small diesel generators than with high-voltage transmission, scrubber sludge disposal, and giant coal-fired power plants. These utilities are small rural cooperatives and municipal utilities. They are largely distribution systems that buy power rather than generate it, although some have small generating units, and others are banding together to buy into large power plants. Small utilities typically have small staffs and small budgets—plus some special R&D needs that EPRI has been attempting to ascertain and satisfy.

Small utilities do, of course, have an interest in the larger issues: high-voltage transmission, coal-fired power plants, and the like. "No utility is an island, especially a small distribution system," emphasizes Guy Farthing, manager of member services at EPRI. Because the electricity wholesaler's generation and transmission costs are passed on to the buyer, the small utility feels the reverberations of the national (and international) fuel, labor, and technology markets. And adds Farthing, "We all share many of the same technical problems."

Special needs

But small utilities have certain special R&D needs, too. Take distribution: "We have over 40% of the distribution lines in the United States and serve 9% of the population," explains Lowell Endahl, R&D coordinator for the National Rural Electric Cooperative Association (NRECA), which represents almost all of America's nearly 1000 rural electric cooperatives. This disproportionate amount of line can aggravate the ordinary distribution problems that all utilities, regardless of size, must deal with. Ferocious ice storms snap more line; blustering winds instigate greater line gallop; woodpeckers, dry rot, and fire attack more poles.

When distribution systems finally succumb, the smaller utility is often in a poor position to make repairs, according to William Shula, manager of EPRI's Distribution Program. While larger utilities may have adequate trucks and staff to efficiently search out broken lines, a small utility may have limited manpower and equipment to implement repairs. Shula observes that sometimes a utility may depend on repair arrangements with outside contractors.

Preventive research

Given the distribution problems of small utilities, it's not surprising that a list of R&D suggestions offered by participants at a recent EPRI workshop for small utilities held in Kansas City included preventive-type distribution research: de-icing coatings and antigalloping devices for distribution lines, a pole tester to check for dry rot, lightweight polymer distribution insulators, and a solution to the ubiquitous woodpecker problem.

Some of these needs are being addressed by EPRI. For example, field-testing is scheduled to begin soon on low-cost Polysil* (polymer silica) distribution insulators. Other solutions may not be far away. EPRI has developed simple, low-cost antigallop devices now being tested on transmission lines. These devices may prove useful on distribution lines as well. Other distribution needs, such as de-icing distribution line coatings, a pole tester, and woodpecker control, have been included in EPRI's Five-Year Plan and will be considered for EPRI research funding at a later date, according to Shula.

Conventional generation

Generation, too, is an area where small utilities have some special R&D interests. "Only a handful of rural electric distribution systems own their own generation," says Lowell Endahl. About one-third generate electricity through jointly owned generation and transmission coops, and about two-thirds buy electricity from other systems.

Among municipal utilities and public utility districts, about 680 of a total of 2228 generate at least some of their own electricity, according to statistics from the American Public Power Association (APPA), which represents about 1400 of the United States publicly owned power systems. The remaining utilities buy all their power from outside agencies. As mentioned earlier, a growing number are forming joint-action agencies to build commonly owned power plants or to buy into existing power plants.

What small utilities typically do own, remarks John Dougherty, director of the Electrical Systems Division at EPRI, is "small, conventional generation." For instance, 514 municipal utilities own diesel units. The diesels have proven to be "reliable workhorses," as Eric Leber, APPA's director of energy research, puts it, but fuel supply trouble may be just around the corner. The present-day diesels require premium distillate fuel. Because today's small-utility diesel owner would be physically and financially incapable of whisking a coal or nuclear plant on line in event of a premium fuel shortage, APPA feels research is necessary to either alter diesels to accommodate lower-quality fuel or develop alternative fuels the existing

*Polysil is an EPRI trademark.

diesels can burn.

Diesel R&D turned up on the Kansas City R&D recommendation list, and a follow-up questionnaire sent to members of the APPA confirmed small-utility interest in this area. Consequently, EPRI and APPA are discussing the possibility of a joint workshop to outline needed diesel research.

Heat recovery also intrigues small utilities, specifically the municipals. The city or town with generation in close proximity to its customers could benefit from heat recovered by such schemes as bottoming cycles, cogeneration, and total energy systems. "This opens up new avenues for district heating and the use of cogeneration for industrial processes," observes Eric Leber. EPRI has a number of on-going and planned projects to investigate heat recovery. One in particular may eventually prove of interest to municipals, RP1276, which is investigating the economics and technology of several dual-use energy systems.

Load-forecasting techniques are another area in which small utilities have a growing interest. Two distribution load-forecasting models for urban areas have been recently developed by EPRI. The models, which will be available toward the end of 1979, should prove useful to municipal utilities and those coops that serve urban areas, according to Shula.

As small utilities become increasingly concerned about ensuring their power supplies at affordable prices, more and more join forces to buy into existing baseload power plants or to build jointly owned new plants. Rural coops form generation and transmission cooperatives called G&T coops; publicly owned utilities form joint-action agencies. The generation interests of these combined organizations—for instance, large coal-fired and nuclear power plants—more closely resemble the interests of larger utilities.

R. L. Rudman, EPRI planning director, summed up the situation when he said, "Each segment of the electric utility industry will face challenges in the years ahead. Whether an organization is a large investor-owned utility or a small municipal or rural coop system, new concepts and new technology will be required to supply electric demands in the future. EPRI has anticipated many of these needs and has planned a balanced and comprehensive research program that is already producing useful 'products' for each member utility."

Defining needs

Through such efforts as the Kansas City workshop, EPRI has been sounding out small-utility needs and trying to meet them more closely to stimulate small-utility involvement in the Institute. "We need their memberships," concedes Shula, "but, more important, we need to tap all available resources to give us guidance. We need their input to identify their specific R&D needs." While the results of EPRI research are available to the public at large, members steer the course of the research. "By joining EPRI, small utilities can put the spotlight on some problems that are peculiar to small utilities, as well as to the fringe areas of larger utilities, and get something done about those problems," emphasizes Dougherty. Both NRECA and APPA have research programs of their own, but as Farthing points out, both programs are small in terms of total dollar resources. "By joining with other segments of the utility industry," adds NRECA's Endahl, "we can do so much more together than any of us can do independently."

Yet small systems have a long way to go before they are as active in R&D matters—and in EPRI—as are the larger systems. In terms of actual members, EPRI represents 143 of 272 investor-owned utilities (usually larger systems); 247 of 933 rural electric cooperatives; and 189 of 2228 municipal utilities and public utility districts. On the basis of kilowatt-hour sales, that translates into about 80% of the investor-owned sector (which had sales of some 1418 GWh in 1976); about 25% of the rural coop sector (which had sales of about 117 GWh); and about 35% of the public power sector (which had sales of some 227 GWh).

Nevertheless, memberships among the typically smaller rural coops and public power agencies are growing apace, as Farthing is quick to note. In 1975, for example, 134 rural electric coops were members, compared with 247 today; in the same year, 139 public power agencies belonged to EPRI, 189 today.

Reasons why

There are several possible reasons for the low membership among small utilities. One of the basic problems, suspects Shula, is the number of small utilities and the difficulty of reaching all of them. "At the small-utility workshop, it was amazing how many people said, 'We didn't know EPRI was doing that research.' It's hard to spread the word among, say, 1000 cooperatives or 2000 municipals." APPA's Leber echoes that observation: "I think most small utilities have heard of EPRI, but I don't believe a sizable fraction are really aware of what the Institute is doing." Getting news of EPRI research out to the far-flung small utilities is vital. "If we don't communicate successfully, the results of EPRI research, the benefits of that research, are lost; without technology transfer, the value of the research is zero," comments Wayne Seden, senior planner and coordinator for technology transfer at EPRI. Institute efforts, such as the Kansas City workshop, provide a means of disseminating that information. "Lots of times you think you need research in something, then find out it's already been done," reports Jack Hicks, manager of Linn County Rural Electric Cooperative, Marion, Iowa, and a member of EPRI's Distribution Task Force. "We find EPRI is already working on most of the problems we can identify, and is often half-way there," adds Jim Miller, manager of engineering services at Lincoln Electric System, a municipal in Lincoln, Nebraska, and also a member of the Distribution Task Force.

Even if a small utility believes that EPRI R&D can be to its benefit, deciding to join can take some persuasion. "Historically, small utilities have not had much R&D," relates John Dougherty, "and the concept of joining a national R&D effort is taking time to get across"—particularly as EPRI has existed only since 1972. Robert Schucker, electric manager at Dover Municipal Power Plant, Dover, Delaware, agrees: "The idea of a national R&D organization is new to us. A small utility with maybe two linemen and one meter-reader can understand paying an electric bill, but to put thousands into a research organization? They have trouble with that."

Potholes on Main Street

Sometimes the hurdle can be one of simple expedience. In the case of publicly owned municipals, for example, town councilmen must weigh an investment in EPRI R&D against other, more immediate needs of the community. "A councilman may say, 'Do you think that EPRI membership is a better use of public funds than patching up those potholes on Main Street?'" remarks Larry Hobart, assistant executive director of APPA. Not surprisingly, the potholes may win. "If the lights aren't out, don't waste money on electric power research," is another common reaction, reports Miller.

The predicament is compounded when town councilmen are not attuned to utility interests. "The man on the board could be a checker in the local supermarket," half-jokes one manager of a small municipal that serves a population of 7000.

Similarly, rural coops—privately owned by the electricity consumers—have an obligation to provide reliable service at the best price, and so an R&D bite for promised future savings may not be easily understood.

Extra effort

One reason for the additional attention now being given to understanding the R&D needs of smaller systems is that small utilities have small staffs and small budgets; they generally do not have the necessary manpower or budget to send representatives to participate effectively on EPRI utility advisory committees and working groups where research policies are hammered out and budget allocations are made. Nevertheless, two representatives from G&T coops and one from a public utility district sit on EPRI's Board of Directors; two representatives from the rural coop sector are on the 26-person Research Advisory Committee; and three representatives from smaller utilities are on the 20-person Distribution Task Force. Two Washington-based EPRI representatives work closely with APPA and NRECA to solicit added input on small-utility needs and feedback on how well EPRI is meeting those needs. Ben Strange is assigned to APPA and the public power agencies at large; Wayne Beatty serves NRECA and the rural electric coops. (Both Strange and Beatty may be reached at EPRI's Washington office, [202] 872-9222.)

Keeping informed

Obtaining information about EPRI's many R&D programs can also be a problem for those utilities whose smaller staffs might not have the time to ferret out news of pertinent research.

APPA and NRECA are making efforts to keep their members posted on EPRI R&D developments through articles in their respective magazines, *Public Power* and *Rural Electrification.* In response to several requests by small-utility representatives, EPRI is considering a research information telephone service at its Washington office—questions about Institute R&D would be forwarded to the appropriate person at EPRI for an answer. (In the meantime, small-utility information requests may be directed through APPA or NRECA or through EPRI representatives Strange or Beatty.)

Even EPRI's technical reports can intimidate a short-handed utility. The literature is certainly welcome, confirms Jack Hicks: "When you have a problem, you'd otherwise turn to old college texts or distribution handbooks that were state of the art 10 years ago. The new information from EPRI acts as a resource base for a small organization." But the reports have a trick of piling up on a scaled-down staff: "I don't mind wading through them, but I'm the exception," comments William Corkran, Jr., general manager of The Easton Utilities Commission in Maryland. Furthermore, "The five- or six-syllable words in tech reports written by PhDs are not written for the average small utility," observes Schucker. Monthly report summaries, available on request in place of full-length reports, were introduced by EPRI in late 1977 and are helping to ease the paper burden.

EPRI's Research and Development Information System (RDIS), a data base with information on some 4400 research projects sponsored by EPRI and by individual electric utilities, is another source of research information for small utilities. The system can be accessed by an interactive terminal over telephone lines, or requests for information may be made by letter or phone.

Chance to achieve

Ultimately, R&D is "a form of specialization," explains Robert Mauro, former director of energy research for APPA and now an EPRI project manager. This particular specialization comes about when a utility's day-to-day, here-and-now needs are being reasonably met, and the utility can devote staff and money to bettering today's systems and planning for tomorrow's. EPRI's pooled-funding approach gives small utilities, with their limited staffs and budgets, the chance to achieve together the research they could never achieve alone.

Cutting Costs Underground

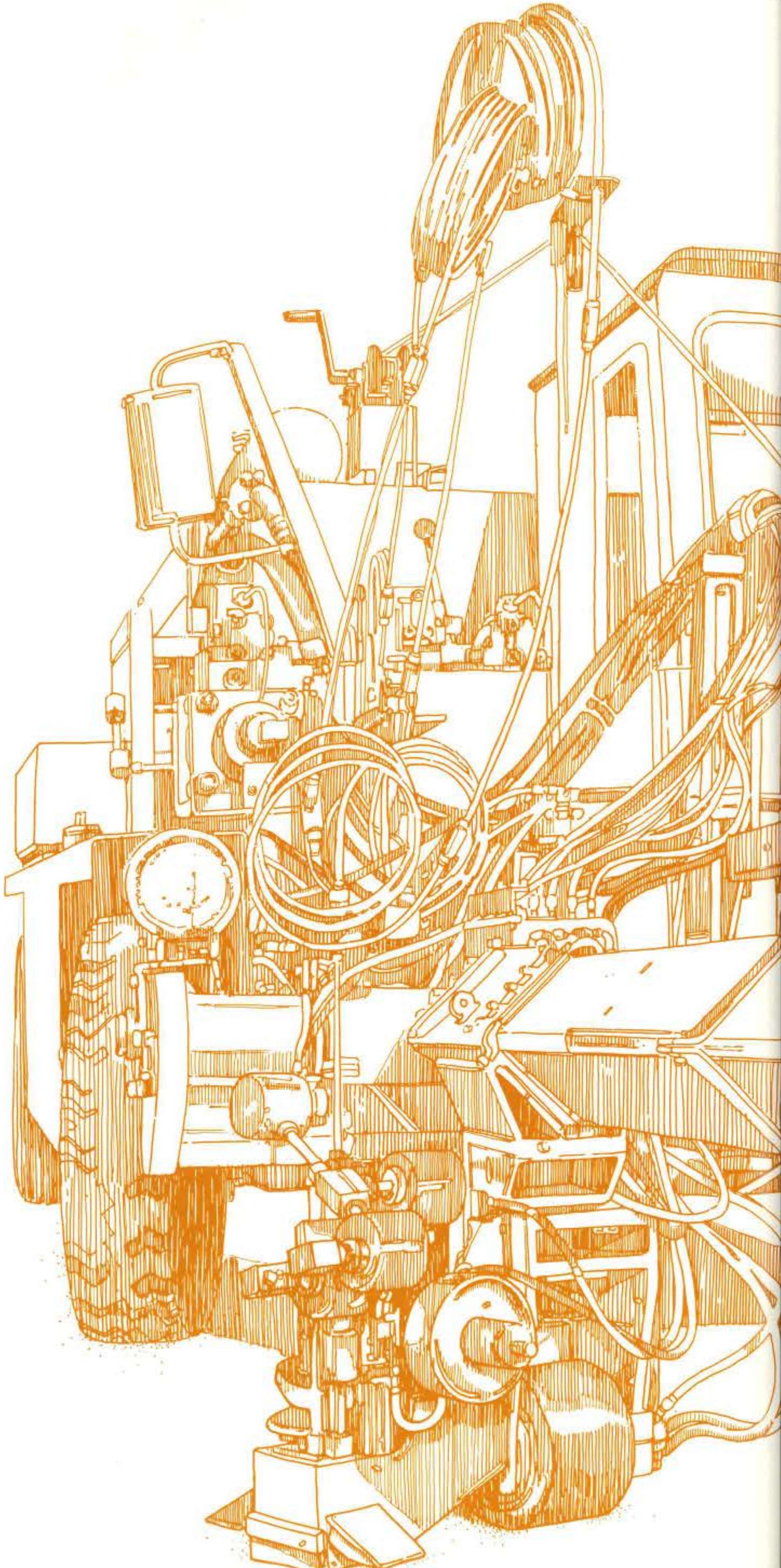
Laying cable in urban areas is disruptive and expensive. But a new water-jet concrete cutter may reduce stresses and costs.

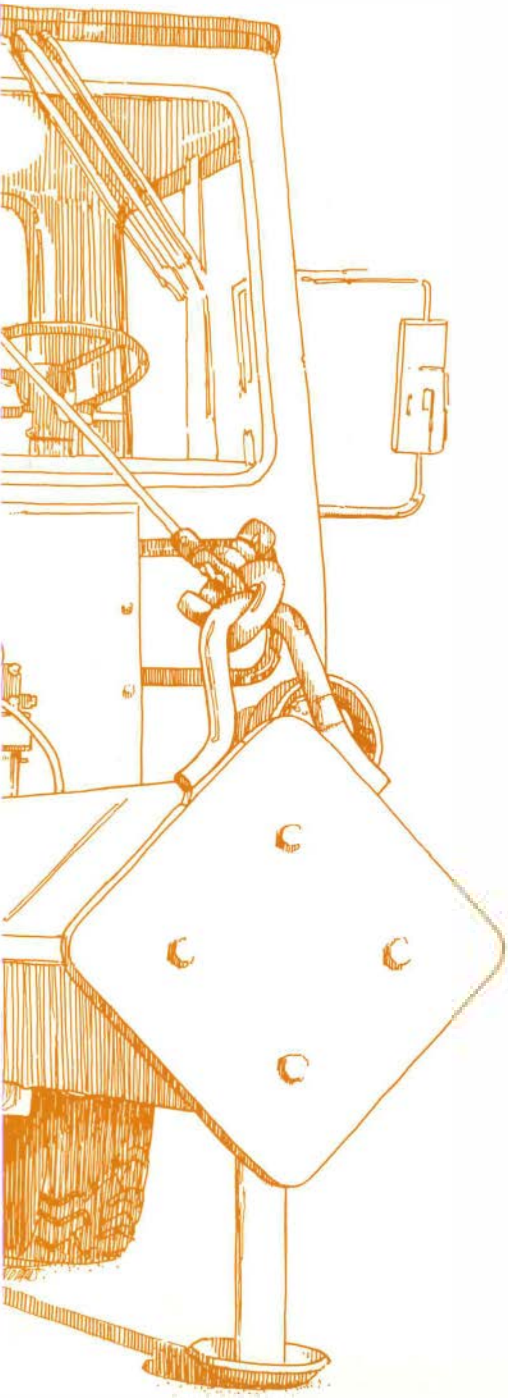
Driving through the center of town to a meeting, you suddenly notice the traffic in front of you slowing down. Reaching a standstill, you open the car window to see what's going on and are jarred by the 100+ dB blast of pneumatic drills that announce road repair or cable laying. As your car crawls past the torn-up roadway, you think about the discomfort, the dust, the delay—and the dollars.

Even though the results of laying cable underground may be more esthetically satisfactory than the presence of overhead lines, the expense is a drawback. Half the total installed cost of a cable circuit is incurred in the processes of trench cutting, cable pulling, trench refilling, and road-surface reconstruction. Added to the expense is the disruption caused by the entire operation.

But EPRI and Flow Industries, Inc., may have found a way to phase out uneconomic trench-cutting methods. Over the last few years, they have developed a water-jet concrete-cutting vehicle that is expected to cut pavement faster in a relatively clean and quiet operation. Most important, the method should reduce costs.

A pneumatic drill or jackhammer uses compressed air to produce the power for dry-cutting; the hydraulic vehicle uses high-intensity water jets at 8 gal/min (0.5 mm^3/s) to cut road surfaces, greatly reducing noise and pollution. Water jets are already an invaluable means of cutting, drilling, and scoring in shoe, clothing, and packaging factories. In fact, Flow Industries manufactures 50-hp (37-kW)





water-jet cutting units for such commercial purposes.

But as a utility workhorse, the EPRI concrete-cutting vehicle requires five times the power and water-jet pressures up to 56 ksi (386 MPa). The vehicle has an articulated boom under which are two kinds of nozzle heads, wide and narrow. When the vehicle operator is ready to cut, say, a 2-ft-wide (0.6-m) trench in an 8-in-thick (20-cm) pavement, he holds the vehicle stationary and positions the boom so that the wide, three-nozzle head can make the first crosscut.

The initial cut, or kerf, is designed to penetrate only half the depth required, that is, 4 in (10 cm). The operator passes the water jet to and fro several times, keeping the nozzle at the optimal standoff distance of 0.25 in (0.6 cm) from the surface. The three-nozzle head is used for this first cut to make a kerf wide enough to accommodate the narrow, single-nozzle head, which is then lowered into the kerf to cut through the remaining depth.

To cut the sides of the trench 5 ft (1.5 m) at a time, the operator turns the boom 90° to the crosscut and makes a half-depth kerf with the three-nozzle head. As before, he automatically exchanges this wide head with the single-nozzle head to cut down to the full depth. The boom is turned 180° to cut the other side of the trench. Then the operator moves the vehicle forward and repeats the crosscut operation. The resultant section of pavement can now be lifted out by backhoe at the utility's convenience.

On an asphalt roadbed 6 in (15 cm) deep or less, this procedure can be speeded up. Because asphalt is relatively soft, the operator eliminates use of the three-nozzle head and makes only one crosscut, the first, to enable the backhoe to begin excavation. To cut a 2-ft-wide (0.6-m) trench in asphalt, the operator uses a special manifold, which is mounted under the vehicle. It is the width of the trench and has one single-nozzle head at each end. In this way, both trench sides can be cut simultaneously at a speed between 1 and 3 ft/min (0.005–0.015 m/s), depending on the thickness of the asphalt.

Flow Industries tested the vehicle on pads of twelve different road-surfacing materials that had weathered for six months. Water-jet performance was studied to determine optimal striking angle, pressure, standoff distance, width of cut, and number of passes needed to cut 8 in (20 cm) of concrete, asphalt, and composite materials.

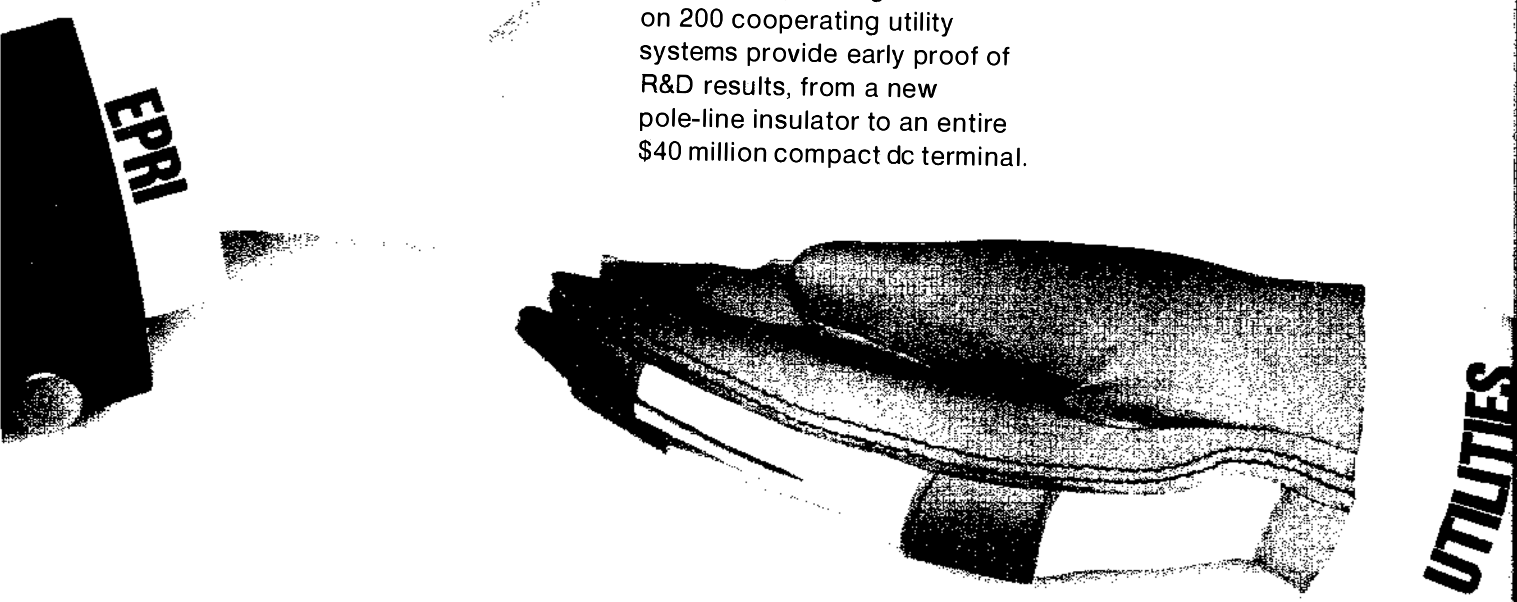
After exhaustive component tests, the time has come for proving the vehicle in the field, or rather, on the street. Questions abound. Will a newly cut piece of concrete flip up when the vehicle moves on, causing problems to the operator or passers-by? Will the water jets work in freezing weather? How likely are leaks? Can the vehicle be maneuvered easily around corners and up and down grades?

To answer these and numerous other questions, Flow Industries is providing a crew to train utility people in using the vehicle. Four utilities in turn will try out the concrete-cutter for six months each, beginning this year: the Los Angeles Department of Water and Power, Public Service Electric and Gas Co., Baltimore Gas and Electric Co., and Consolidated Edison Co. This utility experience will also produce data for projecting costs of operation. These data could be of interest not only to large utilities but also to smaller utilities unable to afford the $150,000–$200,000 for the purchase of a concrete-cutting vehicle. A small utility may be able to rent the equipment or when available, purchase a less-expensive, handcart-size concrete-cutter, manufactured on the same principle as the full-sized vehicle. (The smaller version is only at the concept stage at this time.)

Considering the decrease in available rights-of-way for overhead lines and the increased need for underground transmission because of urban congestion, the water-jet concrete-cutter seems to have a ready market. In fact, it could benefit not only electric utilities but also other utilities and such industries as construction and engineering. But first come two years of road tests. ■

Host Utilities: EPRI's Real-World Laboratories

Authentic operating conditions on 200 cooperating utility systems provide early proof of R&D results, from a new pole-line insulator to an entire $40 million compact dc terminal.



People with no prior knowledge of EPRI's method of operation are apt to ask "Where are the labs?" on first visiting the Palo Alto headquarters. "Where do you do your research?" They see only offices, conference rooms, blackboards, and stacks of reports—not a physics lab, a chemistry lab, or an engineering lab in sight.

As a sponsoring organization, EPRI contracts with laboratories throughout the country. The technology that EPRI conceives, directs, and manages is developed by equipment manufacturers, private and government research organizations, universities, and in a few cases, by utilities. Yet in a very real sense, the member utilities of EPRI, representing over 70% of the industry's output of electric power, constitute EPRI's "in-house" laboratories.

The field testing, shaking down, and debugging of the new technology under development is done on the systems of electric utilities under an arrangement loosely termed *host utility.* These real-world conditions indicate not only if the new technology will work when integrated with an actual utility system but also such factors as manpower, manpower-training requirements, and operating cost.

Defining the relationship

A host utility is one that accepts a piece of new technology—a system, subsystem, component, or technique that EPRI is in the course of developing—and acts as a test-bed to provide actual operating conditions. The magnitude of the technology may vary from a new type of pole insulator or circuit breaker to a $40 million compact dc terminal. It may involve only software, such as testing and debugging a new computer code for utility use, or it may involve a service, such as data gathering or nuclear fuel irradiation.

A host utility relationship must be distinguished from cases where a utility is asked to provide existing information from its records of operation. EPRI asks a host utility to develop new information on the basis of using new EPRI-developed technology. Another characteristic of a host utility project is that the utility contributes funds toward the overall project cost, in addition to contributing personnel and time.

The total number of host utility projects is over 140; counting becomes subjective as many informal relationships are considered. Participating are at least 90 U.S. and 2 foreign utilities (Britain's Central Electricity Generating Board and Canada's Ontario Hydro). There are also 4 U.S. utility-related bodies: power pools, area reliability councils, and state agencies. Southern California Edison Co. has 18 host utility projects; Commonwealth Edison Co. and Consolidated Edison Co. of New York each have 12; Pacific Gas and Electric Co. and Florida Power & Light Co. each have 11. Three other utilities have 9 or 10 projects; 13 have from 5 to 8; and 38 have from 2 to 4. Thirty-seven utilities have 1 project.

A list of host utility projects follows this article. Perusal of the descriptions will indicate the vast range of topics that involve utilities as EPRI research hosts.

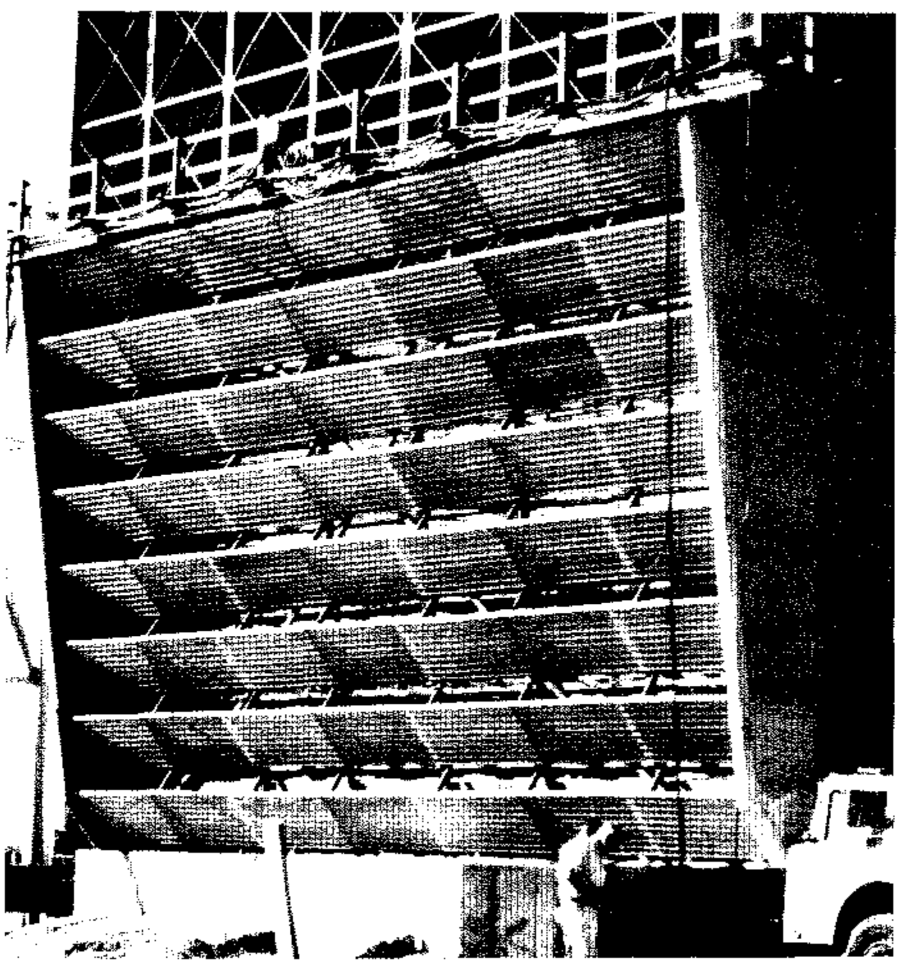
Technology transfer mechanism

Generally speaking, testing is the last step in the development of new technology. But as one utility executive points out, classic laboratory testing, where a new product is put through its paces by its inventor or manufacturer, is a more pedestrian process than the frequently innovative field test involved in an EPRI host project. The host relationship constitutes the first step in an industrywide technology transfer process. The new technology is not only proved but conformed to utility requirements as well.

To find out how the host utility program is working and what it means to a utility to undertake this role, the *Journal* visited several utilities that are significantly involved. Many advantages and a few problems emerged from this informal survey.

Yankee Atomic Electric Co. was among seven utilities whose nuclear plants were instrumented to measure emanations of radioiodine (and other radionuclides) and compare them with regulatory source term (maximum) values. In this instance, sampling filter trains were installed in air vents above the turbine building of the Vermont Yankee plant.

Southern California Edison Co. is monitoring the water consumption of this 200 million Btu/hr, combination wet-dry cooling module at its San Bernardino steam plant. Markedly less expensive than dry cooling alone, the technology may, if proved reliable, find wide use in arid western states where cooling water is both scarce and costly.



One great advantage that might go unnoticed was pointed out by an executive of a relatively small utility that has done considerable pioneering in new technology. "Utilities sit on information resources, data, and experiences that require great effort and time to develop, collate, and evaluate," he observed. "However, it requires the involvement of an external agent, such as EPRI, to provide definition of the technological necessity, as well as the financing, to develop these resources. Without such involvement, the latent information resources would not become available even to the host utility itself, let alone to the country's other utilities."

So, he concluded, "These programs make available to the host and to others, in a unique way, resources that otherwise would remain wrapped in a proprietary flag and buried at the utility or some supplier's office. Eventually, other people would come across the same information, but time would have been lost and more money spent in rediscovering the same thing."

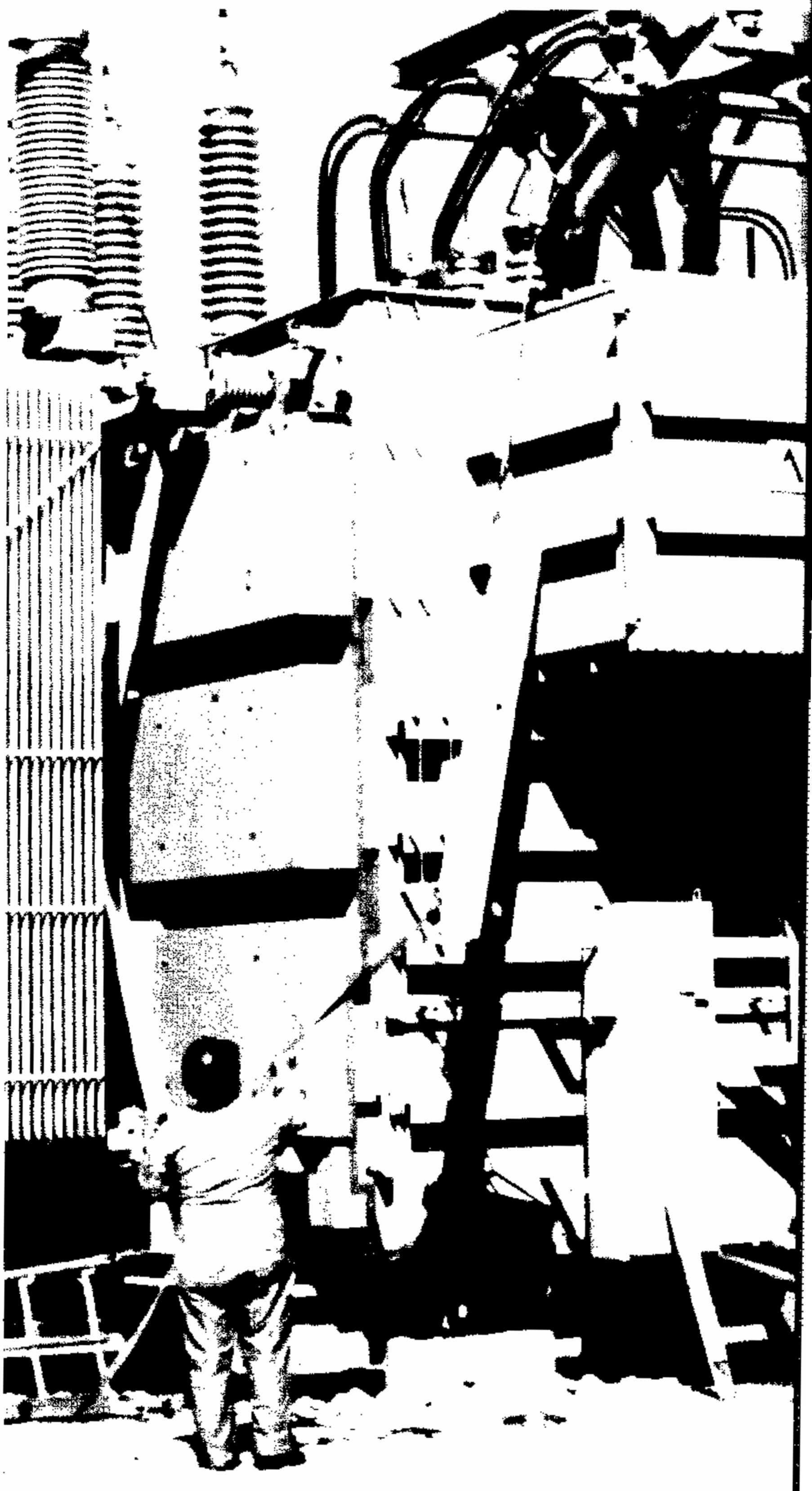
One utility pointed out that it had highly burned fuel in the spent-fuel pool of its nuclear plant, embodying valuable information about the characteristics and condition of fuel and cladding after long burnup, but it could not afford a program to investigate the fuel by shipping samples to a laboratory equipped with hot cells unless EPRI aided with financing. Once extracted, developed, and analyzed, this information was shared with other utilities, to the benefit of all.

Gearing up to be a host

In preparing to bid on a host utility project, the utility research division (or other unit primarily interested in the project) must sell the idea within the company. A great deal of manpower coordination is required between the time a request for proposal is received and the time a demonstration is started. At startup time all operating people are involved, so it becomes a large company investment.

For one large utility whose system is predominately urban, Consolidated Edison Co. of New York, the EPRI–DOE

Wisconsin Electric Power Co.'s Mequon substation was one site for installation and test of enclosures designed to reduce transformer noise primarily by tuning. Dimensions, stiffness, density, and geometry of the steel panels attenuated noise amplitudes at selected frequencies by as much as 15 dBa.



request for proposals to install and operate a 4.8-MW demonstration fuel-cell facility was so important that the company organized itself in a way it had never done before, just to prepare the proposal. According to Robert Bell, ConEdison's assistant vice president responsible for R&D, a task group was formed with representatives of all the principal divisions of the company; a special work area was set aside for its use; and a five-volume, 600-page proposal was produced.

Even before the proposal was submitted, ConEdison began a public education program to explain its significance. "It was imperative to determine community acceptance of the technology," Bell comments. "After all, why develop a technology that won't or can't be used because of public resistance? Just by getting the fuel cell demonstration sited, we accomplished half our objective."

The other half is the technical benefit that accrues from the experience. "It's important to put new technology into the hands of users early," he adds. "Doing so enables us to shape the final version of the equipment so that it can be sited, constructed, and operated efficiently within the working confines of an existing utility system."

Another aspect of the relationship, according to a research manager at a large utility, is that becoming a host utility has many ramifications that should be thought about, provided for, and settled well in advance. A project involving equipment on the utility system will involve operating staffs who need to plan in advance for whatever demands or modifications of routine operations may be required. System planning, electrical engineering, mechanical engineering, construction, and system operations divisions are all likely to become involved, and all need to schedule, coordinate, and provide for training—in advance. Once the company president signs a proposal, the company is legally committed if it is awarded the project, and all this advance planning and coordination must have been taken care of.

Said the vice president for engineering of another large utility, "In certain areas of technology, we are most anxious to be the utility selected to test out new developments. We can get the job done directly without a lot of tangential involvements and at a more realistic cost to the customer, which is, after all, the bottom line. If the new technology is satisfactory here, many other utilities with different characteristics will find it satisfactory also.

"It's a responsibility to be a host utility. There are some areas where it's a burden because additional manpower is required. But we benefit and other utilities benefit. If we accept the responsibility of being a host utility, we must also accept assigning our best people to it and giving our very best effort to the project."

Selection criteria

What are the criteria by which host projects are awarded? There is no single hard-and-fast set but rather a range, applied on a case-by-case basis. A project requiring a construction site, such as the Emissions Control and Test Facility, the 4.8-MW fuel cell station, or the Battery Energy Storage Test Facility, will involve far different selection criteria than a project to install pump-vibration monitors.

Some generalizations can be made, however. Proposals are compared and evaluated on the basis of the amount of cosponsoring funds offered and the services the utility is willing to provide without cost during the installation phase and the operating phase. The number of people to be made available to the project and the degree of their expertise are other important points considered.

Benefits and demands

"If you want to last in this business, you do research. Your survival depends on it!" declares Raymond A. Huse, vice president of PSE&G Research Corp. and a senior statesman of utility industry research in the United States. "As soon as someone else can provide energy conversion cheaper, we're dead," he adds. "Our management is very perceptive about this." His company's parent utility built a big wind generator as far back as 1932 and has been at the forefront of electric power innovation since.

"EPRI host projects keep top management more keenly aware of new technology," Huse says. "If you become a host utility, top management is inevitably drawn in and becomes more involved, even the board of directors. A dozen or so years ago, equipment suppliers were expected to perform research for the industry—it was a job of the manufacturers. EPRI played a key role in bringing about a change, making all in management more aware of the need for research."

PSE&G Chairman Robert I. Smith similarly recalls the time when many utility executives felt that manufacturers should do the hardware development and the federal government should pay most of the cost of demonstration projects. In contrast, the attitude in Washington today is for at least a 50–50 split in funding between the government and industry. Yet large-scale demonstrations of such technologies as solar-electric generation and solvent-refined coal are likely to be so costly that they will require greater government participation, in Smith's view. Under today's circumstances, the only chance of carrying out many needed projects is in a host utility, cost-shared effort.

Other utilities admit candidly that they would probably have gone ahead and built or installed and tested a piece of new technology if no one else in the industry had been doing it under a host arrangement. But doing it in partnership with EPRI means that they can get it done at far less cost than by going alone. Working with EPRI means getting more for the research dollar, one executive declares.

Looking in another direction, a utility system planning vice president asks, "What is the value to utilities of host projects?" And he answers his own question, "It's not a matter of value, it's *essential*. If EPRI doesn't do host utility projects, the work gets too academic. So it's essential. What is the incentive for us? We get valuable by-products.

"It's an advantage to be in the forefront," he goes on. "Of course, we can't be in the forefront on everything—it's been said that a pioneer is a guy with an arrow in his back. But we must be in the forefront in selected areas. The benefit to us is obvious because the product is developed in a proper and timely way. The manufacturers are happy to get the input from a host project; it's better than dealing with tons of paper reports.

"The investment community views a utility as progressive and enlightened if it makes an application of its resources to advances in technology."

New personnel challenges

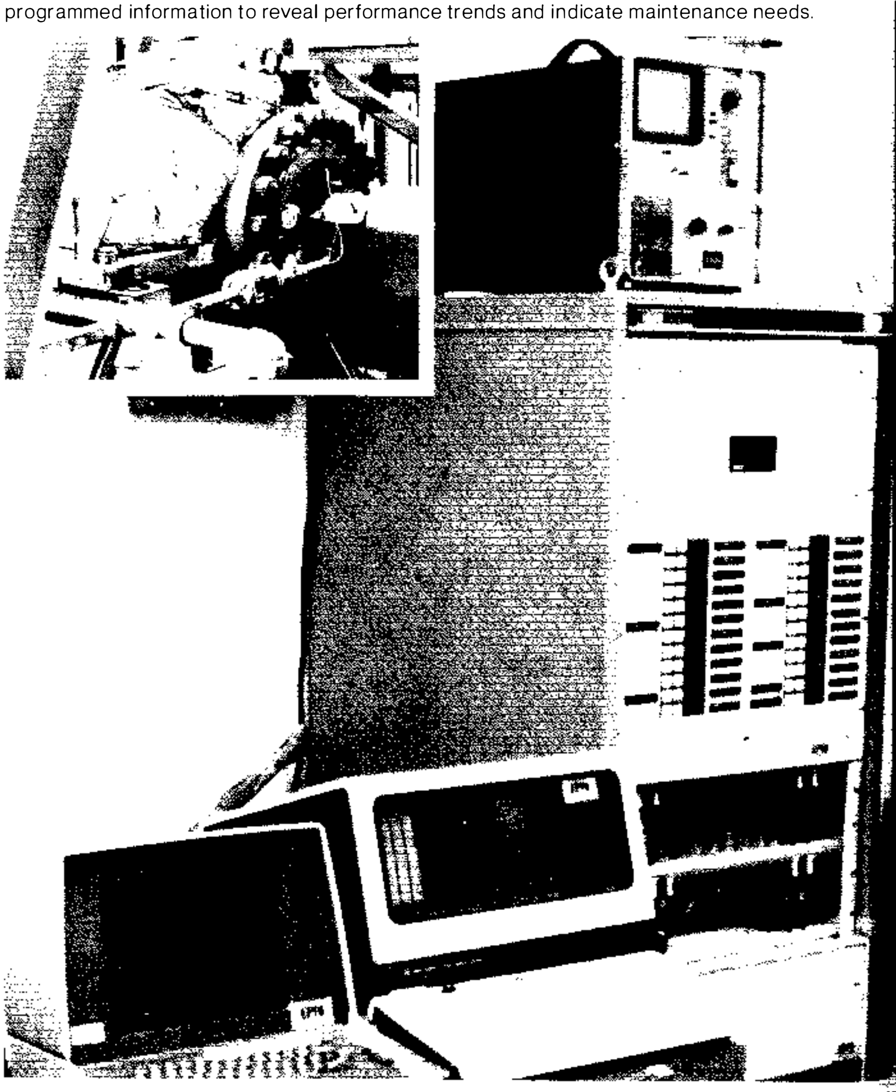
A host demonstration project can be used for more than one purpose, points out another executive. "You are dealing with a real system, not a theoretical system. You get an opportunity to educate zoning boards, utility commissions, federal agencies, and, of course, the ratepayers and public in your area."

Another benefit to utilities is to keep professional staff interested and challenged. "Many of our engineers are faced with work of a repetitive nature," admits an executive of a large utility. "Work on EPRI host projects introduces challenges and exposes them to new technology. They get all charged up. We assign our best engineers to such projects, and in many cases it helps to keep them here. So we find that host utility projects help us attract and retain good people."

Personnel training is still another side benefit from host projects. "The host utility concept is an ideal one when it comes to training people," a project supervisor says. "There is a terrific spin-off: the hands-on experience for engineers and operators. Also, as host utility staff they get involved with some of the specifications for equipment. So it's a great learning experience. The intimate familiarity with the new technology is invaluable; there is no other way that we could provide equivalent training. This is an incalculable advantage to us, and the project cost is a minimal factor by comparison. The fact that our people are able

The Tennessee Valley Authority will operate 10 modified Volkswagen buses that take their fuel at a multipin electric connector. Developed for commercial use in Germany, the vehicles will be used for van pools, courier service, and light hauling during a two-year test of reliability, service needs, patterns of power demand, and characteristics of battery charger operation.

Northeast Utilities is testing this machinery-monitoring and diagnostic system at its Millstone-2 nuclear plant. Transducers set into the casings and bearing caps of pumps, motors, and turbines are linked with a computerized terminal so that vibration patterns can be correlated with programmed information to reveal performance trends and indicate maintenance needs.



to work on these projects is a definite asset to us and probably the biggest single benefit we get from them, bigger than 'being in on the ground floor.'

"Another thing of tremendous assistance to us is being involved with the original debugging of equipment. And seeing a piece of new technology go from the conceptual stage through planning, engineering, fabrication, installation, and test operation is a unique learning experience."

Performance and costs

Host utility work must not only show whether the new technology works but must also show whether its capital cost, operating cost, and maintenance cost are competitive or excessive; whether the new technology is reliable; whether the equipment can be manufactured on schedule, within budget, and with good quality assurance; whether it can be modularized, and so on.

Many problems with new technology stem from the fact that tighter quality assurance, greater cleanliness, and narrower tolerances are required than for much of the technology already in place. Thus a host utility not only breaks the ice to show whether the greater demands can be met but also takes on the associated problems and, often, resulting delays. "You learn a lot, but you have to put up with a lot," comments one utility official with experience on host projects. There is a corresponding advantage in this, too: if the utility is interested in the particular new technology, it can solve the problems in a manner to suit its own system.

Committee structure

"A host utility project is one more link between EPRI and the utilities," one spokesman stresses. "If we only sent a check in the mail, EPRI wouldn't be as effective. Of course, the advisory committee structure is a mainstay of EPRI-utility contacts. But host utility projects are also links that bind us together."

Some host utility projects are monitored by a task force or task force subcommittee. Some have an ad hoc project committee of personnel from EPRI and the host utility, and the project committee may include experts from other utilities or federal agencies. There is enough flexibility to permit adjusting to the particular needs of each project.

All utility people who were questioned felt their participation on such committees is highly significant, providing cross-fertilization of ideas and valuable comments from other committee members that are of direct benefit to the utility.

Another type of industry participation panel is the technology users' group. Much of the technology that has come out of EPRI in its first five years is now struggling for commercialization, and it may be that formation of mission-oriented, special-purpose groups for each technology is the best way to achieve commercialization, one utility research director believes. Each technology would have a highly specific users' group, on a case-by-case basis, along the lines of the users' groups for new EPRI-developed computer codes. Other examples are the users' group for PWR steam generators and the SO_2 scrubber users' conference.

The goal of any demonstration project should be to put the technology into the hands of the users early so they can modify it, if necessary, to have it come out in operable, sitable form, according to a utility research vice president. Correct timing is vital to ensure that the technology itself is timely. It can be as great a mistake to try out a technology too early, before the need for it has developed, as it is to be too late. It should be timed to come when utilities have a need for it.

Management and responsibility

A major sticking point in negotiations has proved to be the question of insurance and indemnification—whether it is the host utility or EPRI that is to be held harmless from possible damage caused by construction or operation of the project, and who pays the insurance premium. Everyone tries to foresee everything that might happen during the period of an agreement; some run for 3 years, some for 5, some for 10.

Then there is the question of who is to call the shots. Some utilities tend to want to do things the way they have always been accustomed to, and they may feel that EPRI, as the research arm of the utility industry, should follow instructions. However, EPRI's management has been instructed by its board of directors to treat utilities in an arm's-length fashion when they are in the role of contractors.

What results is an entire spectrum of case-by-case accommodations. In some cases EPRI retains both program management control and technical management control; in others, it has given up one or the other, or even both. Sometimes control may shift when construction or installation is concluded and operation begins. Sometimes proposed changes in established plans must be approved by the other partner before being carried out.

Mention must be made of another type of demonstration that involves a three-cornered relationship. This occurs when a manufacturer places equipment on a host utility system and EPRI invests dollars in evaluation of the new technology. Examples are the flue gas desulfurization process developed by Japan's Chiyoda International Corp., which is being tested at Gulf Power Co.; and another technique, an aqueous carbonate process for the same purpose, developed by Atomics International Division of Rockwell International Corp. and being tested on the system of Niagara Mohawk Power Corp. EPRI's role is to help evaluate the technology on behalf of all utilities. In return for its financial support, EPRI requires that the developer agree to license the process so that utilities are not restricted to a sole source of supply.

It isn't clear to what extent the host utility relationship may be unique to EPRI. What does appear to be clear, however, is that it has been more highly developed and is being used more often by the electric power industry than by any other U.S. industry.

EPRI Host Utility Projects

Fossil Fuel and Advanced Systems Division

RP202	Effects of coal by-products in soil	Southern California Edison Co.
RP203	Economics of low-Btu gasification	Tennessee Valley Authority
RP225	Assessment of energy storage for utility systems	Public Service Electric and Gas Co.
RP255	Battery Energy Storage Test Facility	Public Service Electric and Gas Co.
RP376	Geothermal heat exchanger performance	San Diego Gas & Electric Co.
RP462	Effects of smoke and corrosion suppressants on gas turbine emissions	Public Service Electric and Gas Co.
RP529	Effects of low-NO_x firing on corrosion, slagging, and operation of utility boilers	Arizona Public Service Co.
RP530	Effectiveness of gas recirculation for NO_x control in coal-fired boilers	Allegheny Power Service Corp.
RP536	Test and evaluation of the Chiyoda-121 scrubber	Southern Company Services, Inc.
RP537	Improved lime/limestone scrubbers	Tennessee Valley Authority
RP549	Residential solar heating and cooling experiment	Long Island Lighting Co. Public Service Co. of New Mexico
RP554	Instrumentation and evaluation of a solar water-heating system	New England Power Service Co.
RP556	Environmental baseline data for Heber geothermal site	San Diego Gas & Electric Co.
RP630	Improved process control for scrubbers	Southern California Edison Co.
RP649	Residential solar-assisted heat pump	Potomac Electric Power Co.
RP725	Emissions Control and Test Facility	Public Service Co. of Colorado
RP729	Economic assessment of fuel cells in electric utilities	Public Service Electric and Gas Co.
RP733	Ozone dosage and contacting for condenser biofouling control	Public Service Electric and Gas Co.
RP734	Acoustic emission and vibration signature analysis of fossil-fueled plant components	New England Power Service Co.
RP738	Performance testing and modeling for wet/dry cooling towers	Southern California Edison Co.
RP782	Demonstration of NO_x destruction in fuel-rich burners	Oklahoma Gas and Electric Co.
RP789	Development of advanced heat pumps	Niagara Mohawk Power Corp.
RP842	4.8-MW fuel cell power plant	Consolidated Edison Co. of New York, Inc.
RP844	Solar heating and cooling in commercial buildings	Alabama Power Co. Arizona Public Service Detroit Edison Co. Florida Power & Light Co. Northeast Utilities Public Service Co. of New Mexico Public Service Indiana
RP898	Boiler corrosion when firing refuse-derived fuel	Wisconsin Electric Power Co.
RP922	Definition and conceptual design of a small fusion reactor	Pacific Gas and Electric Co.
RP923	Comparison of solar-absorption and vapor-compression residential cooling	Texas Electric Service Co.
RP925	Commercial solar-augmented heat pump	Southern California Edison Co.
RP981	Aqueous carbonate flue gas desulfurization	Niagara Mohawk Power Corp.
RP988	Methanol as a turbine fuel	Southern California Edison Co.
RP991	Penetration analysis of fossil-fueled and advanced systems	American Electric Power Service Corp. Iowa-Illinois Gas and Electric Co. Middle South Services, Inc. Niagara Mohawk Power Corp. Pacific Power & Light Co. Philadelphia Electric Co.
RP1029	Multicoal cleaning system	Pennsylvania Electric Co.
RP1030	Coal-oil slurry-stabilizing agents	New England Power Service Co.
RP1034	Load cycling of drum boiler power plants	Tennessee Valley Authority
RP1079	Baseline data on utilization of low-grade fuels in gas turbines	Florida Power & Light Co.
RP1081	Preliminary engineering design of underground pumped-hydro and compressed-air storage	Middle South Services, Inc. Potomac Electric Power Co. Public Service Indiana
RP1083	Analytic and engineering analysis of advanced compressed-air storage system	Central Electricity Generating Board (U.K.)

RP1084	Analyses of energy storage systems	Commonwealth Edison Co. Detroit Edison Co. Duke Power Co. Florida Power Corp. Middle South Services, Inc. Potomac Electric Power Co. San Diego Gas & Electric Co.
RP1088	Load leveling on industrial refrigeration systems	Tampa Electric Co.
RP1089	Cool storage instrumentation and data verification	Baltimore Gas and Electric Co. Boston Edison Co. Consolidated Edison Co. of New York, Inc. Duke Power Co. Georgia Power Co. Kansas City Power & Light Co. Kansas Gas and Electric Co. Kansas Power and Light Co. Ohio Power Co. Philadelphia Electric Co. Potomac Electric Power Co. Public Service Indiana Salt River Project Southern California Edison Co. Union Electric Co. Virginia Electric and Power Co. Wisconsin Electric Power Co.
RP1090	Heat storage instrumentation and data verification	Blackstone Valley Electric Co. Brockton Edison Co. Central Vermont Public Service Corp. Connecticut Light & Power Co. Consumers Power Co. Granite State Electric Co. Jersey Central Power & Light Co. Luzerne Electric Metropolitan Edison Co. Nodak Rural Electric Cooperative, Inc. Ohio Power Co. Pennsylvania Electric Co. Potomac Edison Co. Roseau Electric Cooperative, Inc. Wisconsin Power & Light Co.
RP1131	Particulate and trace element emissions from oil-fired plants	Consolidated Edison Co. of New York, Inc.
RP1133	Simulation studies of gasification–combined cycles in power systems	Philadelphia Electric Co.
RP1136	Energy conservation and load management of electric vehicles	Southern California Edison Co. Tennessee Valley Authority
RP1180	Analysis of alternative coal-fired utility systems	Tennessee Valley Authority
RP1181	Porous dike intake structure	New England Power Service Co.
RP1191	Instrumentation of utility-sponsored solar experiments	Cambridge Electric Light Co. Kansas Power and Light Co. Pacific Gas and Electric Co. Public Service Co. of New Mexico
RP1197	Upstream removal of hydrogen sulfide from geothermal steam	Pacific Gas and Electric Co.
RP1234	Solvent refining of coal	Southern Company Services, Inc.
RP1235	SRC-II combustion test	Consolidated Edison Co. of New York, Inc.
RP1258	Absorption steam stripping process development	Tennessee Valley Authority
RP1264	Titanium L–1 turbine blade performance	Commonwealth Edison Co.
RP1274	Utilization of heat rejected from major transformers	City of Seattle, Dept. of Lighting
RP1351	Energy conservation through reduced air infiltration	Public Service Co. of Colorado
RP1400	Coal-cleaning test facility	Pennsylvania Electric Co.
RP1406	Monitoring of stabilized scrubber sludge	Columbus and Southern Ohio Electric Co.
RP1413	Utility requirements and options for fusion	Carolina Power & Light Co. Duke Power Co. Long Island Lighting Co. Northeast Utilities Pennsylvania Power & Light Co. Public Service Electric and Gas Co. Utah Power & Light Co.
RP1455	Coal-oil mixture firing	New England Electric System
RP1456	High-intensity ionizer test	Tennessee Valley Authority
RP1459	Texaco gasification–combined-cycle demonstration plant	Southern California Edison Co.

Electrical Systems Division

RP68	EHV transmission technology	Bonneville Power Administration
RP119	Mechanical performance of multiple conductors	Bonneville Power Administration Consumers Power Co. Florida Power & Light Co. Portland General Electric Co. Southern California Edison Co.
RP134	Coupling capacitor transformer	Baltimore Gas and Electric Co. Potomac Electric Power Co.

RP212	Control of wood decay	Bonneville Power Administration Commonwealth Edison Co. Consumers Power Co. Pacific Gas and Electric Co. Pacific Power & Light Co. Salem Electric Cooperative Virginia Electric and Power Co.
RP213	Compact dc terminal	Consolidated Edison Co. of New York, Inc.
RP214	Chemicals to control tree growth	Metropolitan Edison Co.
RP281	Prototype fault current limiter	Southern California Edison Co.
RP436	Sonic detection of corona in transformers	Commonwealth Edison Co.
RP560	EHV current transducer	Bonneville Power Administration
RP565	Heat-pipe-cooled epoxy bushings	Southern California Edison Co.
RP570	Distribution load forecasting and planning	Pacific Gas and Electric Co. Salt River Project
RP579	Transformer noise abatement	Wisconsin Electric Power Co.
RP655	EHV reactor/capacitor switch	Bonneville Power Administration
RP657	Ceramic oxide surge arresters	Bonneville Power Administration
RP668	Electronic current transducer for HVDC	Los Angeles Dept. of Water & Power
RP670	Mathematical techniques for dynamic analysis	Arizona Public Service Co. Bonneville Power Administration Mid-Continent Area Power Planning Pool
RP671	Field test of conducting compounds for URD cable	Long Island Lighting Co.
RP745	Simulation techniques for interconnected systems	Arizona Public Service Co.
RP748	Combustible gas-in-oil detector	Consolidated Edison Co. of New York, Inc.
RP750	Static VAR generator	Minnesota Power & Light Co.
RP751	Frequency analysis of transients on transmission systems	Florida Power & Light Co.
RP753	Study of electric fields in substations	Columbus and Southern Ohio Electric Co.
RP763	Coherency-based dynamic equivalents	East Central Area Reliability Council
RP764	Long-term system dynamics digital simulation	Florida Power & Light Co. New York Power Pool Pacific Gas and Electric Co.
RP848	HVDC insulator flashover tests	Los Angeles Dept. of Water & Power Southern California Edison Co.
RP849	Transient performance of loads during disturbances	New York Power Pool
RP850	Distribution automation	Carolina Power & Light Co. Detroit Edison Co. Long Island Lighting Co.
RP930	Vapor-cooled transformer	Empire State Electric Research Corp. Niagara Mohawk Power Corp. Southern California Edison Co.
RP931	Ice-release coating for air disconnect switches	Cleveland Electric Illuminating Co.
RP996	Compact capacitor	Consolidated Edison Co. of New York, Inc.
RP997	Synchronous machine stability study	Long Island Lighting Co. Ontario Hydro Potomac Electric Power Co. Toledo Edison Co.
RP1047	Hierarchical control of power systems	Cleveland Electric Illuminating Co. Southern Company Services, Inc. Tampa Electric Co.
RP1048	Strategies for economic power dispatch	New York Power Pool Northern States Power Co. Philadelphia Electric Co.
RP1096	Longitudinal loading tests on transmission lines	Wisconsin Power and Light Co.
RP1097	Study of dc fields and converter stations	Minnesota Power & Light Co.
RP1138	HVDC-AC system interaction from ac harmonics	Bonneville Power Administration
RP1139	Distribution data base design	Consolidated Edison Co. of New York, Inc.
RP1141	Study of lightning current magnitude through distribution arresters	Central Power and Light Co. Cleveland Electric Illuminating Co. Detroit Edison Co. Duquesne Light Co. Florida Power Corp. Florida Power & Light Co. Georgia Power Co. Houston Lighting & Power Co. Ohio Edison Co. San Antonio Public Service Board South Carolina Electric & Gas Co. Texas Electric Service Co.
RP1205	Geomagnetic-induced current	Minnesota Power & Light Co.
RP1209	Distribution fault current analysis	Consolidated Edison Co. of New York, Inc. Florida Power & Light Co. Georgia Power Co. Kansas City Power & Light Co. Montana Power Co. New York State Electric & Gas Corp. Pacific Power & Light Co. Pennsylvania Power & Light Co. Public Service Co. of New Mexico Southern California Edison Co.
RP1278	Transmission line conductor fatigue life research	Alabama Power Co.
RP1281	Field evaluation of Polysil* insulators	Bonneville Power Administration Florida Power & Light Co. Pacific Gas and Electric Co. Pennsylvania Power & Light Co. Southern California Edison Co.
RP1285	Detection of high-impedance faults	Pennsylvania Power & Light Co. Rochester Gas and Electric Corp.
RP7829	Extruded solid dielectric cable	Consolidated Edison Co. of New York, Inc. Georgia Power Co. Southern California Edison Co.

*Polysil is an EPRI trademark.

Nuclear Power Division

RP130	Power distribution benchmark data acquisition from reactor cores	Georgia Power Co.
RP218	Field evaluation and pump strain monitoring system	Public Service Electric and Gas Co.
RP274	Collecting samples of gaseous radionuclides	Baltimore Gas and Electric Co Jersey Central Power & Light Co. Metropolitan Edison Co. Northern States Power Co. Rochester Gas and Electric Corp. Wisconsin Electric Power Co. Yankee Atomic Electric Co.
RP306	Fuel element irradiation	Consumers Power Co.
RP402	Fuel bundle irradiation	Philadelphia Electric Co.
RP497	Plutonium recycle fuel element irradiation	Commonwealth Edison Co.
RP503	In situ response testing of platinum resistance thermometers	Duke Power Co. Florida Power & Light Co.
RP509	Operating and fuel performance data	Commonwealth Edison Co.
RP510	Fuel bundle irradiation	Philadelphia Electric Co.
RP586	Fuel bundle irradiation	Arkansas Power & Light Co. Baltimore Gas and Electric Co. Yankee Atomic Electric Co.
RP600	Measuring radioiodine in environment	Commonwealth Edison Co. Jersey Central Power & Light Co.
RP611	Lead 17 × 17 assembly irradiation of high-burnup fuel	Virginia Electric and Power Co.
RP613	Determine radioactivity in low-level waste	Baltimore Gas and Electric Co. Boston Edison Co. Commonwealth Edison Co. Consumers Power Co. Duke Power Co. Jersey Central Power & Light Co. Northeast Utilities Northern States Power Co. Rochester Gas and Electric Corp. Tennessee Valley Authority Wisconsin-Michigan Power Co. Yankee Atomic Electric Co.
RP706	Electric chemistry and corrosion test	Yankee Atomic Electric Co.
RP711	Fuel bundle irradiation	Duke Power Co.
RP769	Performance measurement on training simulators	Tennessee Valley Authority
RP816	Provide aging data for Class 1E electric equipment	Gulf State Utilities Co.
RP824	Vibration monitors on pumps	Northeast Utilities
RP829	Study of incipient defects in irradiated fuel rods	Commonwealth Edison Co.
RP894	Study of factors limiting nuclear plant availability	Duke Power Co. Florida Power & Light Co. Philadelphia Electric Co. Yankee Atomic Electric Co.
RP895	Fuel failure examination	Jersey Central Power & Light Co.
RP962	Measuring iodine partition coefficient from fuel pools	Commonwealth Edison Co.
RP964	Testing piping systems	Consolidated Edison Co. of New York, Inc.
RP1020	Turbine trip and stability test	Philadelphia Electric Co.
RP1073	Measuring plume dispersion	Iowa Power and Light Co.
RP1124	Turbine chemical monitoring	Arkansas Power & Light Co.
RP1125	BWR nozzle mock-ups for in-service inspection	Jersey Central Power & Light Co.
RP1178	Core performance benchmarking	Southern Company Services, Inc.

Energy Analysis and Environment Division

RP103	Environmental effects of transmission line right-of-way vegetation management	Baltimore Gas & Electric Co. Georgia Power Co. Gulf States Utilities Co. Jersey Central Power & Light Co. Minnesota Power & Light Co. Monongahela Power Co. Pacific Gas and Electric Co. Philadelphia Electric Co. Portland General Electric Co. Public Service Co. of New Hampshire Virginia Electric and Power Co.
RP137	Field monitoring of residential fuel use	Alabama Power Co. Iowa Power and Light Co. New England Electric Service Co. Pacific Gas and Electric Co. Union Electric Co. Wisconsin Electric Power Co.
RP432	Load and use characteristics of electric heat pumps	Arkansas Power & Light Co. Consolidated Edison Co. of New York, Inc. Consumers Power Co. Florida Power & Light Co. Houston Lighting & Power Co. Northern States Power Co. Pacific Gas and Electric Co. Philadelphia Electric Co. Public Service Co. of New Mexico Public Service Electric and Gas Co. Rochester Gas and Electric Corp. Southern California Edison Co.
RP573	Evaluation of a cooling-lake fishery	Commonwealth Edison Co.
RP934	Field evaluation of effects of high-voltage power lines	Commonwealth Edison Co.
RP1101	Group load research and analysis of electric water heaters in single-family residences	Arkansas Power & Light Co. Central Power and Light Co. Mississippi Power & Light Co. Northern States Power Co. Pacific Gas and Electric Co. Portland General Electric Co. Public Service Co. of Colorado Public Service Co. of New Mexico Rochester Gas and Electric Corp. Southern California Edison Co. Tennessee Valley Authority Wisconsin Electric Power Co.
RP1107	Over/under capacity model in electric power system planning	Fifty-nine utilities have or will have an operating model; two regulatory agencies have requested a model.
RP1613	Transfer of electricity supply model to industry	Gulf States Utilities Co.

At the Institute

NUSAC Formed

At the request of the utilities, EPRI has established a Nuclear Safety Analysis Center (NUSAC) to undertake a detailed study of the Three Mile Island accident and to make recommendations for safety improvements in the operation of nuclear power plants.

NUSAC will have a professional technical staff of about 30. One-third will be drawn from EPRI's Nuclear Power Division and the others from utilities, equipment manufacturers, architect-engineers, national laboratories, consulting firms, and the nuclear propulsion branch of the U.S. Navy.

Edwin L. Zebroski, head of the Systems and Materials Department of EPRI's Nuclear Power Division, has been named full-time director of NUSAC. Robert Breen, of the Safety and Analysis Department of that division, is deputy director.

An advisory scientific review board for NUSAC is being assembled. It will be chaired by John Swartout, former deputy director of Oak Ridge National Laboratory and vice president of Union Carbide Corp.

The director will report to the EPRI Board of Directors, and the center will be housed at EPRI but will have its own separate budget. Funding will be provided by special contributions from the utilities. The budget for the remainder of 1979 has been set at $3.5 million.

Initially, NUSAC will focus on the causes of the Three Mile Island accident. Thereafter it will develop technical strategies for avoiding other nuclear plant accidents. Such strategies may involve design, operation, maintenance, operator training, and standby emergency procedures.

NUSAC will coordinate its activities with those of appropriate federal agencies, including the commission of inquiry appointed by President Carter.

Helium May Indicate Uranium Deposits

Measuring helium in soil and groundwater can be useful in uranium exploration programs, according to a report recently released by EPRI—*The Potential of Helium as a Guide to Uranium Ore* (EA-813).

Because helium is a by-product of the radioactive decay of uranium, helium surveying can be used to guide drilling and thus reduce exploration costs for deeply buried uranium deposits. The report notes that helium surveying is most successful when daily fluctuations in helium content are taken into account and that the groundwater technique shows the greatest promise when prospecting over large areas.

"Basically, this report reflects the same attitude that prevailed in industry and government more than three years ago; namely, that helium surveys must be conducted and interpreted with caution," notes EPRI Project Manager Jeremy Platt. "The chief difference now is that more has been learned of the specific difficulties and promise of helium surveying," says Platt. "It can be a valuable part of an exploration program."

As part of this project, researchers tested helium survey techniques over known uranium deposits in the southern Powder River basin, Wyoming; in the Grants–Ambrosia Lake district, New Mexico; and at the Schwartzwalder Mine in Golden, Colorado.

The helium content of soil gas was measured by inserting shallow probes, collecting the gas with hypodermic syringes, and then analyzing the gas samples in a specially prepared mass spectrometer. Helium in groundwater was measured by a similar technique.

In addition to analyses of the easily extractable soil gas, limited surveys of helium in the soil itself were conducted. The presence of radon, one of the radioactive transformations of uranium during its decay, was also surveyed.

To date, surface uranium has been located chiefly by Geiger and scintillation counters (devices for detecting and registering radioactive emissions). These methods are limited by the shallow penetration of radioactive emissions through rocks and soil.

The contractors for this EPRI-sponsored project were Martin Marietta Corp., Denver, Colorado; Earth Sciences, Inc., Golden, Colorado; and Chemical Projects Ltd., Ontario, Canada. EPRI became involved in testing and developing this novel uranium exploration technique primarily to help the utility industry estimate the costs of finding uranium for nuclear power plants, as well as to help the utilities' own exploration efforts. The research project benefited from earlier studies sponsored by DOE.

Improving Combined-Cycle Power Plants

A $5 million research effort to determine if gas turbines can be economically and reliably combined with steam turbines for commercial electricity was announced recently by EPRI.

If the effort proves successful, combined cycles will be one of the most competitive ways of generating power. Combined-cycle power plants are presently fueled with natural gas or petroleum fuels; however, their long-term value will stem from their ability to use coal liquid and gaseous fuels, which are expected to be commercially available by the late 1980s or early 1990s.

In a combined-cycle plant, the exhaust heat from a gas turbine is used to make steam to turn a steam turbine. Gas turbines, used by utilities mainly during peak periods of electricity demand, have not been as reliable as utilities would like.

The first effort of the four-year EPRI program calls for a part-by-part scrutiny of existing gas turbines by three turbine manufacturers to pinpoint present design and component limitations.

Approximately $1.5 million in contracts have been signed with General Electric Co., United Technologies Corp., and Westinghouse Electric Corp., who will analyze their respective turbine designs and use the data to develop new, improved design concepts.

EPRI then expects to fund an additional $3.5 million to design a totally new combustion turbine–combined-cycle plant, using the best ideas from the first phase of the program.

Combined-cycle plants firing oil or gas can boost thermal efficiencies by 15–20% over conventional oil-fired steam plants, and the capital cost to utilities is about 33% less.

Combined-cycle plants are used commercially today and account for 1% of the nation's total generating capacity. EPRI officials project that by the year 2000, combined-cycle plants could account for 12% of the U.S. generating capacity.

Calendar

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

JUNE

25–27
Second EPRI Symposium on Electric Utility Load Forecasting
Denver, Colorado
Contact: Debbie Bridgeman (415) 855-2624

25–28
National Fuel Cell Seminar
Bethesda, Maryland
Contact: Arnold Fickett (415) 855-2554

JULY

8–13
Fifth International Conference on Wind Engineering
Colorado State University, Colorado
Contact: Phillip Landers (415) 855-2307

AUGUST

12–17
International Conference on the Fouling of Heat Transfer Equipment
Indian Lake, New York
Contact: Isidro Diaz-Tous (415) 855-2826

SEPTEMBER

19–21
International Symposium on Controlled Reactive Compensation
Varennes, Quebec
Contact: Narain Hingorani (415) 855-2309

OCTOBER

16–18
Second National Symposium on Environmental Concerns in Rights-of-Way Management
University of Michigan
Contact: Robert Kawaratani (415) 855-2589

25–26
Topical Conference: Particulates
St. Louis, Missouri
Contact: Guy Farthing (415) 855-2392

Electric Vehicle Demonstration

The start of a major study to assess the state of the art of electric vehicles and their potential effect on utility systems was announced recently by EPRI.

The EPRI contractor for the two-year demonstration project, the Tennessee Valley Authority (TVA), will procure up to 20 electric vehicles for its employees to drive, test, and evaluate under specific road conditions. The cost of the project to EPRI is $560,000 for the vehicles and data acquisition system hardware.

Evaluation tests of manufacturers' models have been under way since April 1978 at Southern California Edison Co. in Rosemead. After evaluating four different vehicles, Volkswagen Corp. was chosen last month to supply the first 10 electric vehicles for the project. A second manufacturer will be selected if another vehicle qualifies when SCE completes its test program.

TVA has developed a demonstration plan and will start to acquire data when the first vehicles are delivered in June 1979. Electric vans will be used in the demonstration because electric work vehicles for industry will probably be introduced commercially before passenger vehicles. A significant market for the vans is foreseen in the electric utility industry, in telephone and postal service, and for other commercial uses.

According to Ralph Ferraro, EPRI project manager for electric vehicle research, the results of the project will assist electric vehicle users in determining how to manage fleet operations, train operators, and provide maintenance and service facilities.

"Data will be used to establish the key requirements for viable, larger-scale electric vehicle demonstration programs," said Ferraro. "Determining the characteristics of present-day electric vehicles in an electric utility system and identifying high-priority areas for research, design, and development are the major objectives of the project."

Although widespread use of electric vehicles has significant potential for a favorable impact on utility power systems, indiscriminate battery-charging operations could adversely affect utilities by adding to peak power demands. Researchers plan to assess this possibility and examine ways of minimizing undesirable impact.

EPRI officials note that this project should make a major contribution to the national effort of commercializing electric vehicles and reducing dependence on foreign oil.

Corrosion Effects Investigated

The damaging effects of corrosion, including equipment failure and resultant power outages, were discussed at the recent EPRI Corrosion Advisory Committee meeting in Palo Alto, California. Some 65 representatives of U.S. and foreign utilities and vendors attended the meeting. Discussing the corrosion effect of chloride and oxygen on steam generator tubes are (from left) Tom Passell, EPRI project manager; Richard Begley, manager of steam generator engineering, Westinghouse Electric Corp.; and James Cobble, dean of the graduate school, San Diego State University.

Geopressured Water/Gas

Miles below the earth's surface lies a potential energy source—geopressured water and gas—the subject of a new study by Southwest Research Institute (SWRI) for EPRI.

Researchers at SWRI, San Antonio, Texas, recently started work on a one-year project to determine how existing technology can extract and use this energy source to produce commercial electric power.

EPRI Project Manager Vasel Roberts reports that EPRI's aim is to evaluate the economic aspects of the geopressured resource and demonstrate its use in the mid-1980s. "It is a domestic energy source that could reduce U.S. dependence on imported fuels if significant quantities can be recovered and the cost is not prohibitive," he says.

Geopressured zones are known to exist at depths from about 5000 to 25,000 feet (1500–7600 m) along the Gulf coast of Texas and Louisiana, and there is evidence that zones probably exist in other sedimentary basins of the world. No one, however, has attempted to bring the fluid (high-pressure brine) to the surface in large volume for commercial recovery of the natural gas it contains because it has been considered too expensive, Roberts says.

Estimates of the potential power production represented by the thermal energy of the geopressured resource along the U.S. coast of the Gulf of Mexico range from practically zero to several thousand megawatts. Estimates of the resource's gas content (methane) are as high as 3 quadrillion cubic feet.

Existing gas recovery systems could be used to remove the methane from the brine by reducing the pressure, according to Roberts. However, recovery of the gas alone may not be economical. "We anticipate having to convert the heat and pressure to electric energy to reduce the overall cost of energy production."

Those who are examining various concepts for converting the resource's heat and pressure into electric energy maintain that the temperature of the geopressured brine is probably too low in most cases (120–200°C; 250–400°F) for efficient conversion with conventional steam technology. One concept being examined for converting geopressured heat involves a binary-cycle (two-fluid) system. In this system the heat in the geopressured brine is transferred to a secondary working fluid, such as isobutane, which is vaporized to drive a turbine.

Researchers are also investigating ways to strengthen existing equipment for converting pressure into electric energy so that it can tolerate the high pressures, temperatures, and corrosive fluids of this resource.

Washington Report

DOE's wind energy program is focused on capital cost reduction and utility integration. Commercialization hopes for central power generation are pinned to advanced machines clustered in energy parks.

Integrating an often unpredictable electricity source into a power grid with predictable needs is one of the chief challenges facing DOE's wind energy program. So far, according to DOE, research demonstrates that wind energy conversion systems (WECS) show promise of economically displacing energy from oil-fired generation when the wind is blowing.

Although the $61.9 million program is hardly one of the largest at DOE, it has passed milestones that could lead to large-scale commercial applications in the years ahead. Right now, the target is bringing wind generation costs down to the range of fuel oil costs. In some areas of the United States, fuel oil for electricity generation can run up to 4¢/kWh. Officials with the DOE program believe wind generation, under favorable conditions and by clustering a number of wind generators in a single energy park, could come close to reaching that 4¢ oil-cost target.

Avenues of research

Research has concentrated on a number of wind turbine generators in the 100–200-kW range. Three in the 200-kW range are either operating or under construction, serving diverse small utilities. A fourth will be linked to a larger power grid in Hawaii. A larger wind machine, with the capability of generating 2 MW and designed for a site with an average 18-mph wind, is (in DOE vernacular) to go "on the air" later this year in North Carolina.

EPRI's wind activities are closely linked to the DOE effort. Most recently, according to EPRI's Edgar DeMeo, the Institute has contracted with Arthur D. Little, Inc., to evaluate data that DOE is collecting in its wind turbine generator field test program. The purpose of this effort is to "establish a solid communications link from a utility perspective between these federal experiments and the utility industry," DeMeo said.

In addition, EPRI has developed a methodology that will allow utilities to assess the role and value of centralized wind generation in their own service areas. Specifically, it will help to estimate how much new, conventional generation can be deferred (capacity credit) as a result of installing wind machines, how much energy can be displaced, and what types of fuels would be affected.

With that project completed, EPRI is now doing a similar study for distributed wind systems. These would consist of generators or groups of generators tied into a utility's subtransmission and distribution systems. Both the centralized and decentralized studies are being carried out by General Electric Co.

Wind energy has an advantage among exotic energy systems in that it has been successfully employed both in the United States and in Europe. However, when low-cost imported oil became available in the decades following World War II, wind electric systems lost their economic advantage, and the technology was shelved by utility companies. Following the sharp rise in oil prices and the growing uncertainty of future supplies, the economic attraction of wind energy is being reevaluated.

Dan Ancona, DOE's program manager for large wind systems, cited two prevailing opinions the research program has had to come to grips with. The first, he said, is whether wind machines can be synchronized and operated with the existing elements of a large, modern power generation system. The second is the question of possible power surges caused by unexpected wind gusts. The DOE research program, which has been carried out with NASA's Lewis Research Center of Cleveland, Ohio, is finding positive answers to both those concerns.

Reducing costs

While integrating WECS into an existing electricity production system and power grid may be a key concern of utility operations managers, there are a number of other important R&D avenues being explored. As might be expected, they focus on the major question of cost.

Up to now, wind machines have been mounted on costly, rigid towers. The construction of the blades, which for the 2-MW model stretch as wide as the wingspan of a Boeing 747, has followed aircraft design, with an emphasis on light weight. One main line of research is to move toward cheaper, flexible towers and lower-cost welded steel for the blades. With the blades and hubs accounting for half the cost of present machines, the potential for savings is significant.

The R&D program has been divided into a number of phases. The smaller machines of 200-kW output, called MOD-0A designs, have been built, installed, and maintained by Westinghouse Electric Corp. The 2-MW machine soon to operate at Howard's Knob, North Carolina, to serve the Blue Ridge Electrical Membership Corp., is designated MOD-1. And the new machine with the hoped-for lower cost features is the MOD-2. Detailed design on the MOD-2 is being performed by Boeing Engineering & Construction, and DOE is expected to select sites for it late this spring. The elapsed time from fabrication to operation is about one year. As many as three MOD-2 machines may be built on one site to test the clustering of machines.

Advances have been made beyond the MOD-1 design by contractor General Electric Co. and by others to the point where it is unlikely that more than one demonstration of this type will be constructed. MOD-1 sits atop a 140-ft (43-m), truss-type tower; its two 100-ft (30-m) blades are angled away from the tower in a cone arrangement to capture wind blowing past the tower. For that reason it is called a downwind system. Designed to produce optimal power at 18-mph average windspeed, the system is characterized by rigid components that prevent oscillation.

The MOD-2 will be a very different machine. It will employ a 200-ft (61-m), pole-type tower and the 2.5-MW generator will be turned by a 300-ft (91-m) diameter rotor. The rotor will be teetered on the main drive shaft. This is called an upwind system because the blades face the wind. Both the blades and the tower will be flexible. Building on helicopter technology and the advanced design capabilities now available, the machine will be more "loosey-goosey," in the words of one program manager with General Electric Co., and the less rigid system will help damp out oscillation.

The aim of this innovation is to reduce costs. Design and construction of three MOD-2 field test generators is estimated to cost $27 million. Per unit costs for the 100th machine in production are expected to be $1.75 million, which is the target cost for commercialization. The $1.75 million capital cost, when combined with expected operating expenses, will result in 3.3¢/kWh electricity, assuming the machines are gathered into a 25-machine cluster producing about 62 MW.

In addition to the cost advantages and technological improvements, MOD-2 has another important feature. Whereas MOD-1 attains optimal operation at 18-mph windspeed, MOD-2 attains optimal operation at 14-mph average windspeed. This should increase the number of potential sites for wind machines. About 30% of the land area in the United States has 14-mph or higher average windspeeds. Research is being conducted to define specific locations with such suitable average windspeed.

Field tests

Wind energy, while producing no wastes and using a renewable resource, is not an unmixed blessing. There are land-use concerns, questions of visual impact of the machines and towers, possible local (up to 2 km, or 1.3 mi) interference with television signals, and safety questions involving such problems as ice shedding by blades under adverse weather conditions. In one case, the government arranged for the concurrent installation of a cable television system because the wind turbine could cause disruption of signals to television receivers on Block Island, Rhode Island, the site of a MOD-0A field test.

Other MOD-0A field tests are at Clayton, New Mexico, where the machine serves a municipal utility, and on Culebra Island, Puerto Rico. At Clayton, the wind machine substitutes for generating equipment operated on either natural gas or oil. Although the machine experienced some blade cracking, the problem was corrected after officials determined that the yaw mechanism, which turns the nacelle and rotor to the wind, put excessive loads on the blades. The Clayton machine has operated for more than 3000 hours and has produced 300,000 kWh of electricity over an 18-month span. The Puerto Rico demonstration, like the Block Island wind generation facility, is designed to test the use of wind machines in small, isolated communities where wind power may offer immediate advantages over high-cost power sources, according to DOE.

In addition to the government work, four private firms are concentrating on large wind energy systems. Wind Power Products, Inc., Seattle, Washington, has a contract with Southern California Edison Co. to build a 3-MW wind machine near Palm Springs in southern California. Three other firms involved in private wind energy projects are Energy Development Co., Hamburg, Pennsylvania; WTG Energy Systems, Angola, New York; and Alcoa Corp., Alcoa Center, Pennsylvania. There are also major wind energy programs in the United Kingdom, Sweden, Denmark, and the Federal Republic of Germany.

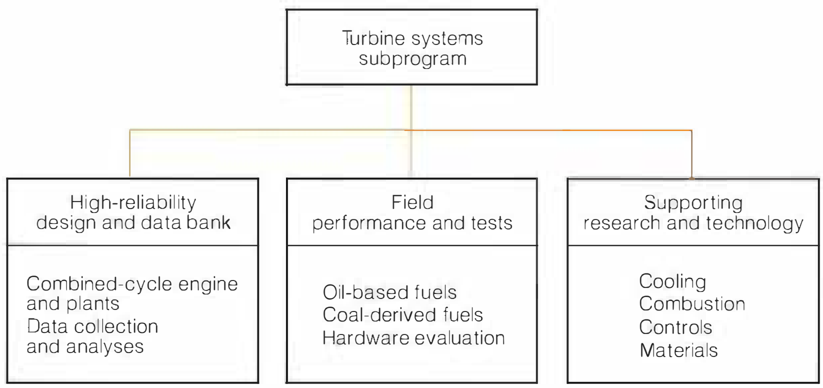
R&D Status Report
FOSSIL FUEL AND ADVANCED SYSTEMS DIVISION

Richard E. Balzhiser, Director

TURBINE SYSTEMS

Research on turbine systems is part of the Power Generation Program and has the following main objectives. The primary objective is to develop and demonstrate a combustion turbine–combined-cycle power plant system that will reliably, cost-effectively, and environmentally be compatible with the use of coal-derived fuels in meeting base and intermediate loads. The secondary objective is to improve the operating performance characteristics of combustion turbines for peaking service. To achieve both objectives, research projects focus on the development and demonstration of technologies that will improve combustion turbine system reliability and fuel flexibility and will reduce emissions and costs (i.e., reduce capital as well as life-cycle operating and maintenance costs). These projects are grouped into three areas, as illustrated in Figure 1.

Figure 1 The organization of the turbine systems subprogram.



High-reliability design and data bank

The main goals of this project group center on the design of a combined-cycle power plant with increased operational reliability. Other goals are to collect and analyze data from existing combustion turbine power plants, both simple- and combined-cycle.

The high-reliability combined-cycle plant design project (RP1187) was recently initiated (*EPRI Journal*, June 1978, pp. 17–21). Preliminary results from reliability investigations and field data analyses indicate that a new centerline-design combustion turbine will be able to achieve a target availability of 95% and the total combined-cycle plant will be able to achieve a target availability of 90%. These performance indexes are for distillate oils; projections for coal-derived fuels are yet to be made. Currently, the manufacturer-contractors see the key problem area to be the achievement of EPRI's planned target of 9000 operating hours between forced shutdowns and 18,000 operating hours between major maintenance outages.

The final report on a recently completed project (AF-911) evaluated future utility needs for combined- and/or simple-cycle systems and identified research areas that may resolve known problems. A survey was conducted of 38 utilities, representing over 50% of the generating capacity of domestic utility combustion turbines. The report indicates that the primary reasons for choosing combustion turbines were short installation lead time and relatively inexpensive capital cost. The major equipment problems were caused by instrumentation and control failures (which decrease starting reliability) and corrosion of components in the hot gas path (i.e., combustion liners, transition pieces, and first-stage expansion turbine stator and rotor components). The performance and service factors most needing improvement were given as reliability (starting and operating) and maintenance. Projects that most needed R&D funding were those to improve service life of hot section components, capability to burn alternative fuels, and starting reliability.

Another reliability project (RP990-2) based on data collection and analysis is determining the operational performance of in-the-field electric utility combustion turbines and is developing an operating procedure guidebook that will document maintenance and operating practices that should improve the performance characteristics of combustion turbines. The data are acquired through a group of combustion turbine maintenance people and/or operators from approximately 20 utilities (the Operational Development Group), who meet twice a year to review selected performance characteristics of their power plants.

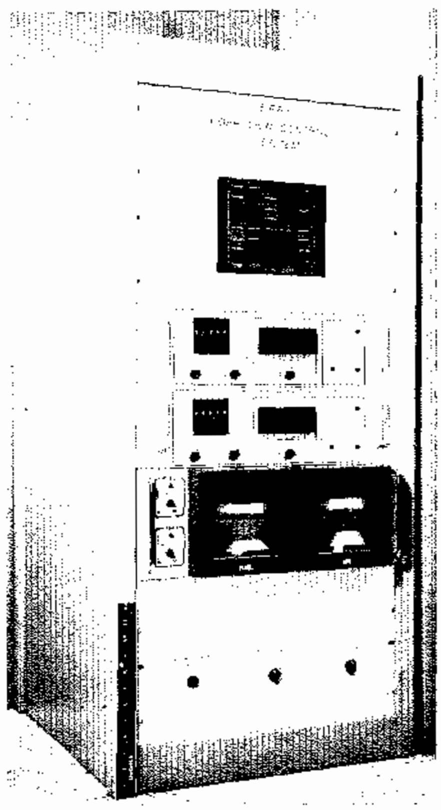
Field performance and tests

The aim of this project group is to field-test alternative combustion turbine fuels and component hardware systems (RP1079). A residual oil fuel test is planned to run a minimum of 3500 hours and record the hardware and operating performance differentials between residual and distillate oil fuels on identical Westinghouse combined-cycle PACE units at the Florida Power & Light Co.'s Putnam Station. As of April 1979, the residual-oil-fired periods were approximately 840 and 960 hours, respectively, for the two combustion turbines on one of the combined-cycle units. The preliminary results indicate that several problems arise for residual oil burns. For example, fuel filters clog so frequently that much larger filters are required. Also, the combustion turbines experienced significant deposition, as well as early signs of hot corrosion. Although deposition results in power loss, FP&L succeeded in restoring most of the loss by using cleaning techniques, such as water wash and pecan shell agents.

Southern California Edison Co. is conducting a project to obtain field-test data on methanol fuel at its Ellwood Station (RP988). The units tested are two FT4CI gas generators, each fired individually by methanol and distillate oil. The test consists of operating the two engines about five hours per day, five days a week, for ~500 hours. After ~40 hours, the test suffered a major delay because of a fire caused by an unrelated event. Preliminary results indicate that the methanol fuel produces NO_x emissions that are nearly 75% less than those from distillate oil.

Another field test will evaluate an instrument and control package developed under one of the supporting research and technology projects (RP643). The hardware package (Figure 2) was developed to allow the utility user to adjust the combustion turbine operation in a manner that will minimize hot corrosion, a factor that significantly affects maintenance in utility turbine power plants. An example of the damage that corrosion can inflict on a turbine blade is shown in Figure 3. Corrosion is caused primarily by alkali sulfates depositing on turbine components in the path of hot gases.

Figure 2 The EPRI corrosion control system ready for field performance tests at Long Island Lighting Co.



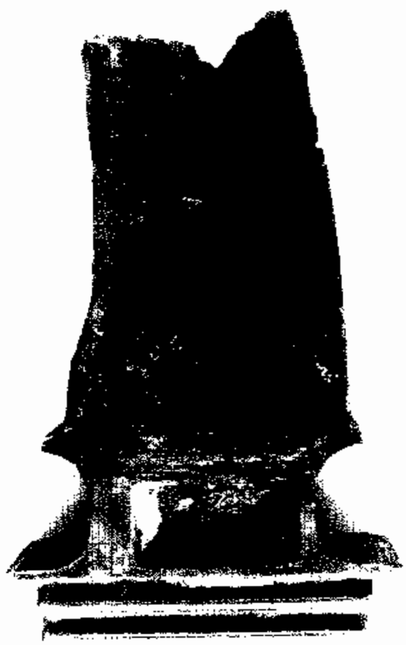


Figure 3 A combustion turbine blade that experienced unacceptable hot-gas-path corrosion.

The corrosion control system was designed by empirically modeling the air and fuel parameters involved in corrosion. An interim report documents the detailed design and prototype hardware development (AF-665). The field tests will be conducted on combustion turbines located at the Long Island Lighting Co.'s Holbrook site.

Supporting research and technology

In this group of projects, engineering data bases are developed for improved cooling, corrosion, combustion, controls, and material technologies that may be included in future combustion turbine systems. The results of these projects serve two major purposes: They provide information for the high-reliability, combined-cycle design project discussed above; they provide R&D solutions to problems on the current generation of turbines.

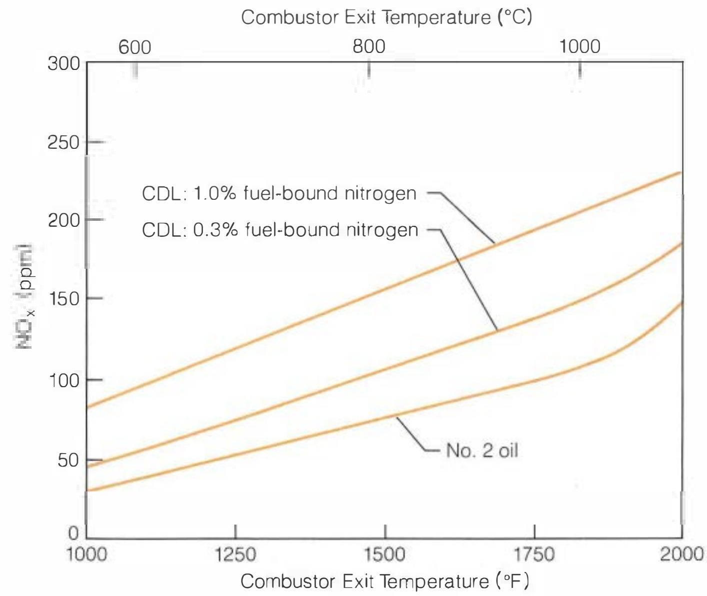
A relatively new project on cooling research and technology focuses on the design and testing under utility conditions of combustion turbines that incorporate advanced cooling concepts on hot section components (RP1319). By using these cooling techniques, a larger difference is achieved between the metal and combustor outlet gas temperatures, thus providing longer life and increased fuel flexibility for the combustion turbines. This project involves all three of the leading domestic manufacturers of combustion turbines, and the task schedules are timed so that the results will be available for use in the EPRI high-reliability combined-cycle power plant project (RP1187).

Water-cooled combustion turbine technology is being developed in cooperation with DOE's high-temperature turbine technology project (RP234). Both stator and rotor water-cooled components have been designed and tested. The results have demonstrated that metal temperatures can be held down to the safer level of 550°C (1000°F) with a firing temperature up to 1550°C (2800°F). Excellent water-delivery and cooling-channel water-distribution characteristics have been shown for rotating components; however, the water collection system still needs improvement. The current emphasis is to quantify the corrosion, erosion, and deposition resistance of components cooled to 550°C (1000°F).

In a combustor research and technology project (RP1040), alternative low-NO_x combustors have been developed for use with 300-Btu gas and have been evaluated in gasifier tests at the Montebello facility of Texaco, Inc. Three combustors were designed, fabricated, and tested. All three met the NO_x emission requirements, and the project results are now being documented.

In another project, design and performance data are being developed for turbine combustors burning coal-derived liquid (CDL) fuels (RP989). NO_x, smoke, and thermal radiation emission characteristics of 10 CDL fuels were measured in a scaled combustor rig. Most of the CDL fuels produced somewhat higher NO_x, smoke, and thermal radiation emissions than distillate oil. These results are consistent with measurements taken for petroleum-based fuels with high aromaticity, low hydrogen, and high nitrogen. Tests have also been made on surrogate fuels, which approximately match these properties. The surrogate fuels are not closely matched in other important properties (e.g., boiling range, specific gravity, and viscosity). However, these surrogate fuels facilitate combustor development tests that require large quantities of fuel and also provide some insight into minimum fuel standards for CDLs used in utility combustion turbines. This project also identified potential problems associated with using CDLs and provided some of the design data needed to resolve these problems. A gratifying test result is the indication that for CDLs with high fuel-bound nitrogen, NO_x emissions are less than would be predicted from a linear scale-up of data from oil-based fuels (Figure 4).

Figure 4 Some preliminary laboratory test results indicate that coal-derived liquids have higher nitrogen oxide emissions than does distillate oil. However, these emissions are not linear scale-ups of the fuel-bound nitrogen.



Ceramics characteristically have much higher heat-resistant properties than currently used metals and alloys. In one of the program's materials research projects (RP421), the proper application of ceramics to combustion turbine components is being examined. Investigations of ceramic coatings 12–20 mils thick indicate that they may provide a good thermal barrier (i.e., reduce metal temperatures some 65°C, or 150°F) for turbine components that are subject to hot-gas-path erosion and corrosion when using clean fuel. However, when used with ash-containing fuels, ceramic coatings spall, indicating that further improvement is necessary for successful utility turbine application. Investigations on monolithic ceramic stator and rotor blade components have also been completed. The results show strength properties that vary widely and if uncontrollable, will lead to a high probability of blade failure in utility applications. Also included in these investigations was work on catalytic combustor ceramic supports. A promising preliminary design was accomplished and temperature profiles through the catalyst were measured. The final report documenting these investigations will be available in mid-1979.

Behavior of ceramics in combustion turbines has been investigated (RP271), specifically to identify the fatigue and creep properties of silicon nitride and silicon carbide at temperatures up to 1350°C (2460°F). The final report describing this project's results is in preparation.

In another materials project (RP545), a prototype ceramic heat exchanger was developed with operational capability up to 1200°C (2200°F) and 35.2×10^3 g/cm² (500 psi). The design included a straight-finned and U-tube component geometry, modular construction, and mechanical joints between tube modules. Fabrication techniques were developed for the finned tubes, U-tube to straight tube joints, and tube to manifold joints. A comprehensive test program is investigating the thermal shock, straight, cycling, burst, and stress rupture characteristics of the material. Preliminary results have shown some problem areas, but in general, the results look encouraging to applications with combustion turbines.

Projects relating to metallic coatings (RP1344) and claddings (RP1460) for utility turbines have just started. These investigations point to improved material life for hot-gas-path turbine components in the 1980s. *Program Manager: Albert Dolbec; Project Manager: Robert Schainker*

INTEGRATED ENVIRONMENTAL CONTROL

To provide minimum-cost, reliable coal-fired power plants, developments in the thermal cycle and environmental control technologies must be coordinated. The complexity of plant operations and designs is sure to increase as new environmental regulations force the use of advanced emission control techniques, and the cost and availability of fossil fuels demand more efficient power generation. The goal of EPRI's research on integrated emission control is to optimize and simplify the designs of conventional pulverized-coal-fired power plants through the systematic integration of environmental control process hardware and basic power generation equipment. With environmental controls representing a major fraction of the costs of a fossil plant, the integrated systems approach may save up to $75/kW for a new plant.

In light of new, comprehensive environmental regulations, electric utilities are faced with the prospect of incorporating several new technologies in series (baghouses, SO_2 scrubbers, NO_x scrubbers) in conventional coal-fired power plants. The interactions between control devices are not well understood and consequently the design of new emission control systems may be dominated by consideration of interface and compatibility problems. Accordingly, EPRI has initiated a project to construct a 2.5-MW pilot facility to assess the integration of air, water, and solid-waste technologies for pulverized-coal-fired power plants. The pilot plant will be assembled at the EPRI test facility at the Arapahoe station of Public Service Co. of Colorado.

Based on experience in using precipitators and scrubbers, compliance with individual emission regulations that demand a series application of several control devices will have a compounded negative effect on unit availability, heat rate, permissible rate of load change, complexity of startup and shutdown procedures, and other plant operations. By using an approach in which the control equipment is considered an integral part of the power generation system these adverse effects can be reduced significantly and costs lowered.

The environmental control hardware often represents up to 40% of the capital cost of a new coal-fired plant. With the advent of more stringent regulations, the capital requirement for controls may double. Approaching compliance problems on a systems basis will ultimately result in benefits for a new 1000-MW plant that may include \$25–\$75 million reduction in capital costs; 5–10% improvement in availability; over 100 Btu/kWh reduction in heat rate penalties; and less complex, more flexible operating procedures. A preliminary concept for an ad-

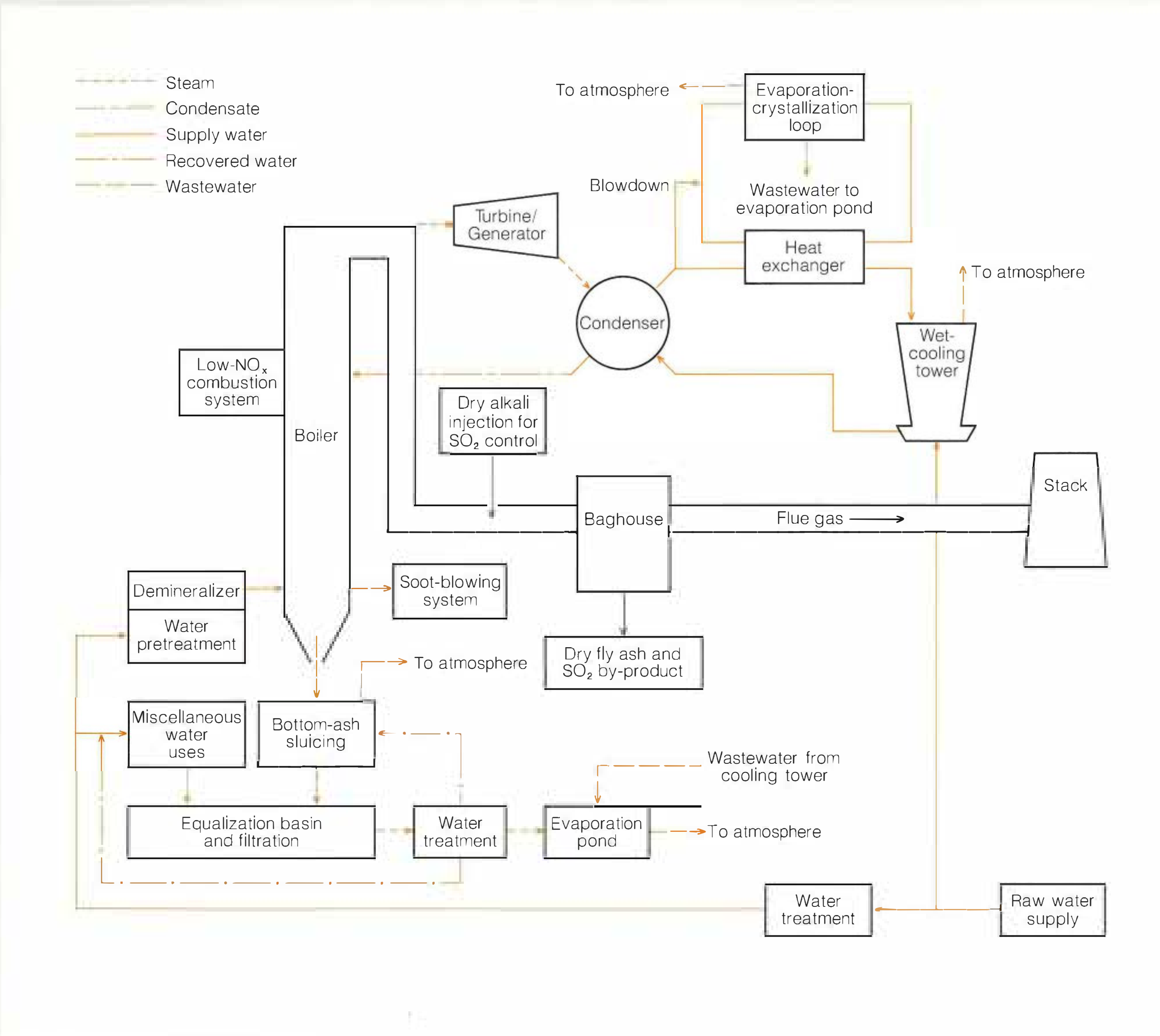


Figure 5 Conceptual schematic of a pulverized-coal-fired power plant burning western coal.

vanced integrated power plant burning western coal is illustrated in Figure 5.

Experimental studies coordinated with the Environmental Assessment Department (Energy Analysis and Environment Division) will be conducted to minimize the adverse impact of environmental controls on basic plant designs and operations and to reduce the number of separate unit operations necessary to satisfy environmental requirements. Startup of the pilot plant is scheduled for late 1979 and testing will extend through 1981. Key technical issues to be addressed are summarized in Table 1. For each of the research efforts, testing will be conducted to define the impact of control technology on power plant operability. The initial interface problems to be addressed are the effects of ammonia carryover from postcombustion NO_x processes. Subsequent research will be focused on interactions among system components. Included will be the implications of using cooling-tower blowdown as water makeup for wet SO_2 scrubbing equipment.

Each of the major components of the pilot plant (baghouse, air preheater, precipitator, SO_2 scrubber, and cooling tower) will be a self-contained, skid-mounted, relocatable assembly. The modular design will permit reconfiguration of the equipment at a given site or at different sites so that alternative emission control strategies can be evaluated and compared. For example, it will be possible to assess and compare the performance of a baghouse located upstream or downstream of a wet SO_2 scrubber. Additional flexibility will permit evaluation of the effect of various operational conditions, including flue gas temperature; flue gas flow rate; NO_x, SO_2, SO_3, particulate, and other air emission concentrations; and makeup water chemistry.

Table 1
INTEGRATION OF ENVIRONMENTAL CONTROLS WITH UTILITY POWER SYSTEMS (PILOT SCALE)

Technical Problem	Research Approach	Application of Results
Environmental control strategy for different coal types. Control of previously unregulated emission species: trace metals, POMs, trace organics, radioactive materials, fine particulates.	Assess capability of existing control devices for alternative process configurations (e.g., baghouse or ESP downstream of SO_2 scrubbers).	Design guidelines and operating specifications to control trace species. Influence regulatory decisions. Define R&D needs.
Disposal of cooling-tower blowdown. Reduction of freshwater consumption by wet SO_2 scrubbing processes. Reduction of reagent consumption for water treatment and SO_2 removal.	Define the effects of using cooling-tower blowdown as scrubber makeup. Investigate various sources of cooling-tower makeup water, cycles of concentration, and treatment methods. Investigate the use of solid wastes from cooling-tower sidestream treatment as reagent makeup in an SO_2 scrubber.	Design guidelines and operating specifications for using cooling-tower blowdown to supply various SO_2 scrubber water needs. Design guidelines for using solid wastes from water treatment subsystems as reagent makeup in an SO_2 scrubber. Design guidelines for cooling-tower water treatment subsystems.
Impact of NH_3-based postcombustion NO_x technologies.	Investigate air preheater deposition/corrosion by NH_3 by-products; conversion of SO_2 to SO_3; NH_3 stack emissions and potential visible plume; baghouse blinding by NH_3 by-products; effects on fly ash resistivity; impact on SO_2 scrubber chemistry and solid wastes.	Influence regulatory decisions. Design guidelines to minimize adverse effect of postcombustion NO_x control.
Disposal of solid wastes.	Collect and characterize solid wastes for alternative configurations of air quality control equipment.	Support EPRI program to influence regulatory actions, develop compliance strategies, and define critical R&D requirements.
Reheat of SO_2 flue gas by a regenerative heat exchanger.	Assess and develop new hardware concepts for heat exchangers at pilot scale.	Design heat exchanger for regenerative flue gas reheat. Define R&D needs.
Elimination of wet SO_2 scrubbing processes.	Evaluate dry alkali injection for SO_2 control.	Design guidelines for dry SO_2 processes.
Control of NH_3 emissions.	Evaluate catalytic processes and operation effects to control NH_3 levels.	Design guidelines to control NH_3 emissions.
Control of moist aerosols from an SO_2 scrubber.	Evaluate the use of wet ESPs.	Design guidelines for the use of wet ESPs.

This pilot-scale plant is a key project in EPRI's integrated emission control research. Emission control technology will be economically developed at pilot scale before technical and financial commitments are made for large commercial equipment. In this way, more reliable, efficient, and operable pulverized-coal power plants will result. Improvements in availability would be realized at every level: components (air preheater, ID fans), major subsystems (baghouse, scrubber, heat rejection equipment, ash/sludge disposal subsystem), and the overall power plant. Similarly, the heat rate penalties associated with environmental controls would be minimized. For one 1000-MW plant, a projected improvement in heat rate of 100 Btu/kWh is equivalent to approximately $18 million (1978 dollars) in fuel savings over the plant's 30-year life. There would be additional savings in capital and operating costs from the engineer's capability of preparing more restrictive technical specifications and the plant's ability to implement systemwide operating and maintenance procedures.

The data could also be used by utilities to influence the setting of new emission standards and the granting of construction permits for a specific site. The anticipated EPA Preconstruction Review procedure will require a major effort by utilities to obtain the required environmental permits. The accumulation of operational and emission data from the integrated emissions control projects will aid utilities faced with proceedings of this nature.

EPRI is funding a parallel research project to assess the prospects for improving the heat rate of conventional pulverized-coal power plants (RP1403). The overall objectives of the project are to:

- Identify and quantify the design details and the economic and operational features of an advanced low-heat-rate pulverized-coal power plant

- Detail R&D requirements necessary to obtain these benefits without adversely affecting plant availability

The project will focus on the basic power generation equipment and thermodynamic cycle to improve thermal performance. The conceptual studies will entail considerations of advanced emission control technologies, which must be incorporated in plant designs. Existing EPRI and other technical and economic data on air quality control, water quality control, solid-waste handling, and heat rejection subsystems will be compiled on a consistent basis and factored into the study. Overall costs, performance, and availability will be quantified for a complete pulverized-coal power plant in which thermodynamic conditions, system reliability, and environmental control equipment have been optimized.

The critical technology needed to realize the benefits of a low-heat-rate plant without jeopardizing reliability will be defined by the engineering study. Implementation of critical technology R&D is likely to follow. In the near future, the environmental control equipment may represent more than 50% of the costs and operational requirements of conventional coal-based power generation systems. Advanced low-heat-rate and conventional designs must incorporate environmental controls; therefore, developments in the thermal cycle and emission control subsystems must be coordinated to ensure optimized, minimum cost, reliable power plants. *Project Manager: Dan Giovanni*

R&D Status Report
NUCLEAR POWER DIVISION

Milton Levenson, Director

A POWER SHAPE MONITORING SYSTEM TO EVALUATE FUEL ROD RELIABILITY

The power shape monitoring system (PSMS) enables fuel reliability to become an integral part of core operation strategy. In the short term, PSMS will provide data that quantify the extent and impact of "violations" and so justify the relaxation of core-operating restrictions. Later on, targets will be to rationalize the margin of operating limits for the emergency core cooling system, the ratios of operating limits for critical heat flux, and core management (e.g., loading schemes). The long-term benefit is expected to be the attainment of near-zero fuel leakage rates, which are likely to be required by regulatory agencies in order to meet man-rem standards for reduced occupational exposure. These developments should result in an increase in plant capacity factor.

Uncertainties in fuel performance have a significant impact on plant capacity (*EPRI Journal*, June 1978, p. 25). For some BWRs, the combination of adherence to a manufacturer's conservative operating recommendations and the fission-product release into the coolant results in up to 6% capacity loss. The cost of industry's fuel-related loss of output now runs at over $100 million per year.

In this project, which began in January 1977, a fully computerized analysis system (Figure 1) is being developed and site-tested for the tracking and simulation of core power changes and for evaluating their effects on fuel-rod performance (RP895). A detailed set of system specifications formed the basis for a comparative evaluation of nine minicomputer systems that might be able to perform the desired PSMS functions. The PRIME-400 was selected by the bid process and is the heart of both the California-based developmental system and the hardware at the Oyster Creek reactor site. Augmenting the services and the facility (Oyster Creek) provided by Jersey Central Power & Light Co. (GCP&L) and General Public Utilities Service Corp. (GPU) is the research work of five contractors:

- Development of fuel reliability evaluation module (FREM)—Scandpower, Inc.
- Development of duty cycle approximation module (DCAM)—Nuclear Associates International, Inc.
- Fabrication of highly characterized assemblies, poolside intercycle examinations, and core characterization—Exxon Nuclear Co., Inc.
- Coordination and development of the

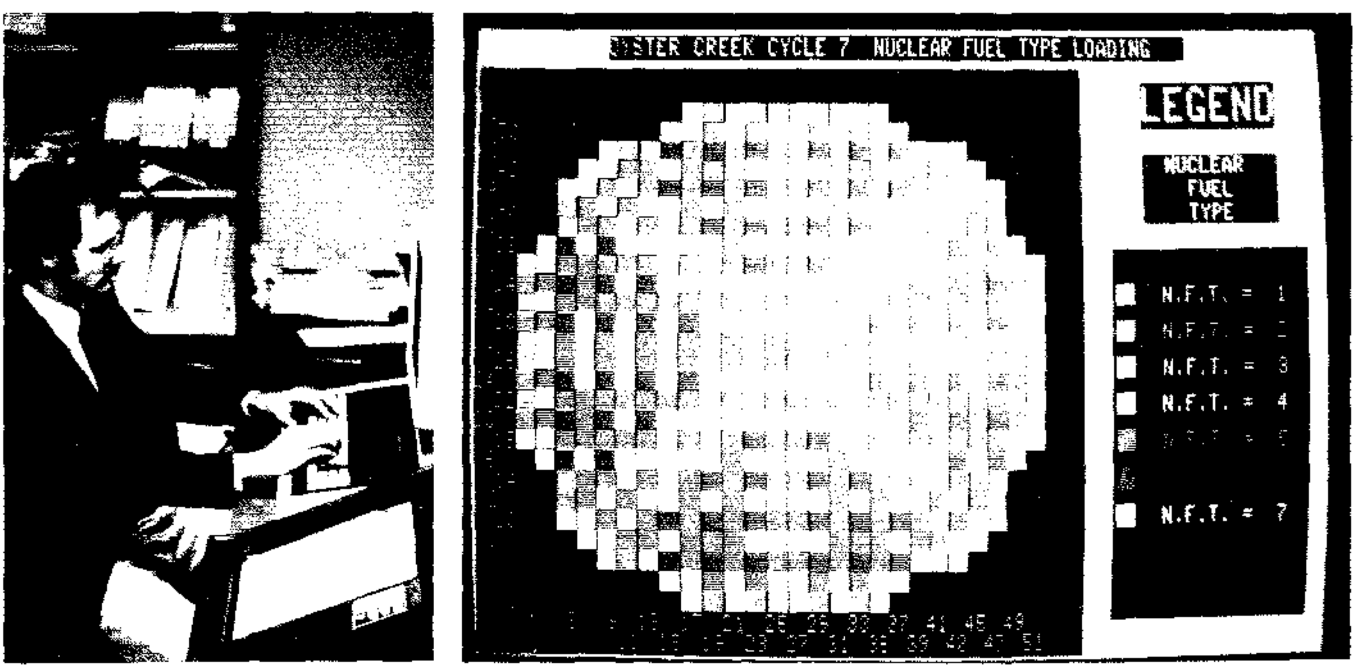


Figure 1 The PSMS is being site-tested at the Oyster Creek BWR. The user-interactive system automatically tracks the state of the core with 3-D calculations of power, exposure, and fuel reliability, or can be used in a manual mode to predict the effects of anticipated operational strategies on these variables. JCP&L staff member uses interactive system at Oyster Creek; typical output display (original is in color) showing core locations for seven fuel types.

computer system to link the PSMS modules—Nuclear Services Corp.

▫ Application of a continuous fission-product activity monitoring system—Babcock & Wilcox Co.

The first PSMS is operating at the Oyster Creek BWR and has been gathering data since the beginning of reactor cycle 8 in December 1978. The PSMS is not part of reactor operations but does acquire core state-point data through a special interface with the plant's SIGMA-3 process computer. Although data transfer occurs every six seconds, only the data from automatically selected state-points are input to the 3-D nodal simulator for an update calculation of the detailed core power shape and exposure history (DCAM calculation). The EPRI NODE-B code and the relative evaluation of local power range monitors (RELPRM) model are used in the DCAM for full-core, quarter-core, or localized (a 4 × 4 grouping of assemblies) simulations, respectively. From these calculations the current linear heat-generation rate and exposure values are obtained for four-rod groups at each of 24 axial assembly nodes in all 560 fuel assemblies within the core. Ten-rod groups are used for the highly characterized assemblies.

If the power-exposure arrays are being updated as the result of a power increase maneuver, system logic may also call for an update of the fuel failure probability. This calculation is performed within the FREM, which is based on a power shock model evaluated previously (RP509). The FREM uses the DCAM output arrays as input for a fuel reliability evaluation.

Output displays are provided for both DCAM and FREM results and can be viewed on a console cathode ray tube (CRT) or a special color television. Hard copy is obtained from a line printer or a printer-plotter. Use of the system is achieved through interactive logic, with a standard keyboard. The user can call for previous state-point or calculated DCAM/FREM data from storage. Any of these data states can then be used as the initial point in a predictive calculation, wherein the user supplies the state-point information for an anticipated series of power maneuvers in order to precalculate power shape changes (e.g., xenon perturbations) or their impact on fuel reliability. This attribute of PSMS capabilities represents the first time that this level of predictive capability is available on a near-real-time basis at a commercial reactor site.

Numerous software improvements were made by JCP&L and GPU to the SIGMA-3 process computer, including changes in the way data are transferred for both the traveling in-core probe (TIP) output and the control-blade position indications. Memory was extended by 64*K*, partly to provide state-point data array storage and transfer.

The PRIME–SIGMA interface provides a high-transfer-rate, long-cable interface to the PRIME-400. The data transfer rate of 20,000 (16-bit) words per second can be a bidirectional exchange, with the PRIME-400 having master control of these block transfers. The PRIME–SIGMA interface was accomplished with a modified system option controller.

The data acquisition and storage module (DASM) logic had its first on-line test during the cycle-8 startup. Transfer of these data every six seconds (the desired rate) to the PRIME was successful and only minor problems arose. Several timing studies of DASM functions were performed to acquire data and store them in the current data file, the circular buffer, or the operating-state file. These tests showed that 3–5% of the system resources are taken up by these activities. Additional DCAM triggering logic will increase that figure, but resource requirements are expected to remain less than the target of 10%.

Five PSMS assemblies containing highly characterized fuel rods were fabricated, shipped to Oyster Creek, and included as part of the cycle-8 core loading. Interim examinations of three of the four cycle-7 PSMS assemblies were completed, and special measurements of fission gas release were made at the site.

Fission-product monitoring was added as a project activity during 1978 to enhance the level of data being taken at Oyster Creek. A computerized, continuous fission-product-monitoring system is now installed and operating at the site.

The monitor, with advanced hardware and software, is set up to measure the fission-product activities in a fluid stream of reactor coolant. Gamma-ray spectra taken in real time will include isotopic description and the time rate of change of isotopic concentrations. The software will announce the significance of those changes in terms of fuel cladding conditions. The data will indicate increased fission-product activity in the coolant and will give an estimated percentage of the defective fuel rods. The fission-product-monitoring system will interact with and give valuable feedback to FREM by providing experimental data pertaining to fuel conditions, which can be compared with theoretical predictions.

Software for both DCAM and FREM has been successfully modified for use on the PRIME-400. A series of burnup steps were evaluated through cycles 5, 6, and 7 to characterize the power, exposure, and reliability status for each node of each group of rods in all assemblies that constitute the cycle-8 core loading. GPU generated a set of constants for NODE-B by using the advanced recycle methodology program (ARMP) logic, and a comparison of selected burnup points throughout the previous cycles indicates the model is working satisfactorily over a wide range of exposure. The matching of DCAM output with that from the in-core sensors is being augmented through the use of the PSMS-acquired cycle-8 data.

This first-generation PSMS logic will be evaluated in detail during 1979. Operating data will be acquired on a continuing basis and will allow an evaluation of the combined SIGMA-3–INTERFACE–PRIME-400 reliability. The ability of EPRI NODE-B to correctly follow the increase in core burnup as well as the power-shape changes will be evaluated through continuing comparisons of analytic results with data from fixed and traveling probe sensors in the core. Data from the continuous monitoring of fission products will be compared with the FREM predictions of fuel reliability. At the end of the year, project accomplishments will be documented in a final report, and the PSMS user's and programmer's computer manuals will be available. The software package can be obtained from EPRI after a license agreement is completed. *Project Managers: Floyd Gelhaus and Alex Long*

MAIN STEAM ISOLATION VALVES

EPRI has initiated projects with Atwood and Morrill Co., the major supplier of main steam isolation valves (MSIVs) for BWRs, and with General Electric Co., the nuclear steam supplier that specifies the MSIV, to improve the specification and design of the valve and its maintenance characteristics (RP1243 and RP1389). The projects will enhance research already being conducted by General Electric, Atwood and Morrill, and utilities.

One limiting factor in the operation and maintenance of a BWR is the MSIV, not so much in its function of opening and closing in the main steam lines and shutting off the flow of steam from the reactor to the turbine but in its ability to isolate the containment and prevent fission-product release outside the containment in the event of a design basis accident.

An MSIV is a 660-mm-diam (26-in) plug valve with the plug and actuator mounted 45° from the in-line axis of the steam piping. The valve, plug, and actuator are large, heavy, and difficult to assemble and disassemble. The plug alone weighs about 720 kg (1600 lb), and therefore removing the actuator and plug for valve seat maintenance is an operation that should be minimized. Because MSIV has the dual purpose of a steam-line valve and a containment-isolation valve, assurance of its operation prior to startup is a technical specification requirement.

Two valves are placed in series in each main steam line, one outside the containment and the other inside the containment. Containment conditions assumed to exist during a worst-case accident require that the valves leak no more than 0.08 mm^3/s ($\sim$10.5 standard ft^3/h) of steam and air from the containment under an assumed pressure of $\sim$379 kPa ($\sim$55 psi). The technical specifications require that the valves in each line demonstrate adequate leak-tight characteristics before the plant begins operation.

Many utilities make conservative checks on their MSIVs, using dry gas and pressurizing the space between the plugs to check leak rates. The pressure tends to lift the inner plug because it is applied below the plug and works against the closing springs rather than being applied from the top of the plug and increasing the closing pressure, as it would in an accident. The dry gas has a higher leak rate than a steam-air mixture, which would be present in an accident.

General Electric plans to check on a number of valves from the time of their manufacture to the time of operation in a BWR. This program is expected to extend over a number of years. The company also purchased an MSIV for testing in facilities at San Jose, California, and developed a machine capable of measuring the seating surfaces of the MSIV in both out-of-roundness and surface smoothness.

Atwood and Morrill have worked with utilities in solving problems with the actuator and the MSIV. The utilities recognize the need to reduce maintenance on MSIVs and have tried many potential solutions, including minor modifications, such as smoothing, honing, and lapping seat surfaces and even changing the position of MSIVs in the plant.

An EPRI review showed that R&D funding could improve the schedule of analysis and testing and could expand and expedite the work in several areas. Some problems overlap; for instance, the specification that the valve stem must backseat when open may be related to a finding by utilities that the plug shows signs of vibrating on the stem in the open position, scoring the guides or plug rails. The thermal expansion requirements for the valve in its role as a steam valve, as it is now designed, may result in valve clearances that inhibit its ability to isolate the containment. The lapping tool used by the manufacturer for final seat facing and for laboratory tests may be almost impossible for a maintenance worker to align and use for lapping in a power plant, where access is difficult and the environment is hostile. This program will identify and develop possible improvements in these areas.

With some modifications, we believe the valve can be made to perform successfully. An encouraging fact is the variation in performance of the valves, even in the same utility generating unit. This indicates that areas of improvement are possible when the failure mechanisms are better understood. It is not unreasonable to suppose the MSIV can perform its dual function with a reduced level of maintenance.

General Electric, in cooperation with EPRI, is now improving the tool for measuring the MSIV seats. Emphasis will be placed on measuring those valves now installed in utility generating units that cause plant maintenance problems. New valves will be measured before plant operation and compared with valves installed and operating in generating plants. To measure possible seat distortion, Atwood and Morrill will apply test loads (equivalent to expected steam pipe loading) to a test valve in the direction of high-stress concentration. General Electric has already measured the effects on the valve seat caused by welding the valves into the pipelines. Design improvements may be possible in existing valves, as well as recommendations for future production. In addition to maintenance, operations, equipment, and other aspects of MSIV work, leak-path mechanisms will be quantified. With modifications and improvements, acceptable levels of maintenance are expected for MSIVs in their dual role in BWRs. *Project Manager: Roy Swanson*

STATISTICAL ESTIMATES OF FRACTURE TOUGHNESS

A novel procedure has been developed to predict statistically the fracture toughness–temperature relationship of a nuclear reactor vessel material simply from knowledge of the Charpy transition curve of the material. The predicted toughness curve can represent average values, as well as such statistical limits as confidence or tolerance bounds. The method is being modified by the developer, William Oldfield, for use on irradiated materials, and initial results are encouraging (RP886-1, RP1021-4, and TPS-77-752).

All man-made structures contain imperfections of one sort or another. The imperfections may be cracks, lack of fusion in welds, embrittled regions, inclusions, and so on. Most such imperfections are benign, having no measurable effect on the structure. However, at some given size, the imperfection must be regarded as having some potential effect on the serviceability of the component. Every practical effort is made to remove those defects that may affect the design performance of the structure. The design performance may be based on reliability, safety, efficiency, maintainability, and the like, depending on the use of the structure.

In the case of nuclear pressure vessels, the assurance of safety and reliability is of primary concern. During fabrication, every effort is made to remove all injurious defects before the component is placed in service. Occasionally, a small imperfection may not be recorded or may escape detection during the fabrication inspections. There is also a possibility that a small crack may develop during service. For these reasons, periodic in-service inspections of the safety-related components are required for nuclear installations. If an imperfection is detected during one of these inspections, its effect on the safety of the component must be assessed.

The flaw evaluation procedure for nuclear pressure vessels is presented in *ASME Section XI, Rules for In-service Inspection of Nuclear Power Plant Components.* For the flaw to be deemed benign to the performance and integrity of the pressure vessel, it must meet two sets of stringent criteria, one for normal operating conditions and one for fault conditions. Specific details of these analyses can be found in EPRI NP-719-SR, *Flaw Evaluation Procedures: ASME Section XI.*

One of the key requirements of this flaw evaluation procedure, which uses linear elastic fracture mechanics, is an accurate knowledge of the plane strain fracture toughness (K_{Ic}) of the materials. How does one go about obtaining such a property for actual reactor systems? The most direct and unambiguous method for establishing the fracture toughness–temperature relationship for a reactor vessel material is to measure it. However, these materials have such high fracture toughness that it requires very large specimens, with thicknesses greater than 500 mm (20 in), to measure the toughness in the fully ductile (or upper-shelf) temperature regime. It is impractical to measure the toughness of each plate, forging, and weldment used in the construction of reactor vessels because as much as one-third of each product form would be used in test specimen fabrication. The cost of testing would probably be more than triple the cost of a reactor vessel. Additionally, it is impossible to irradiate these types of specimens in a commercial reactor vessel surveillance program to measure toughness degradation, if any, from fast neutron exposure. Direct K_{Ic} measurement is not a viable method for developing the toughness-temperature inputs for a flaw evaluation analysis.

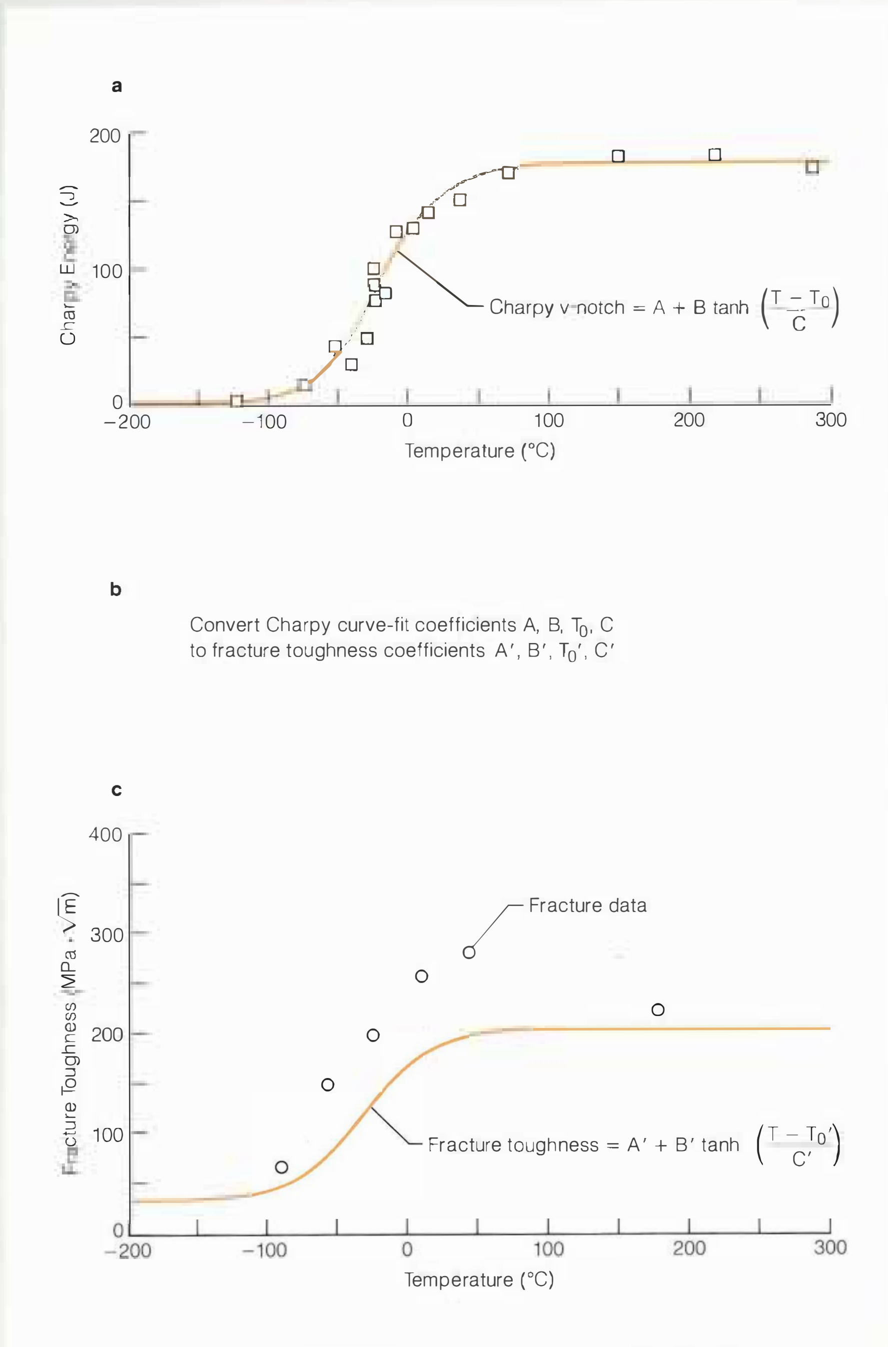
There are methods available to conservatively estimate K_{Ic} from smaller fracture toughness specimens that have been developed with the elastic-plastic fracture methodologies. The operating reactor systems do not normally have the small fracture toughness specimens in the surveillance capsules; newer plants, however, do have them. The surveillance programs for all systems do have Charpy impact specimens from some of the beltline materials (vessel materials surrounding the core) to assess the radiation-induced shift in the fracture-mode transition temperature. Therefore, the most useful scheme is one of estimating fracture toughness from Charpy data.

There are a number of empirical Charpy-toughness correlations in the literature. In addition, an analytically developed correlation is the product of research performed under EPRI funding at the Lawrence Livermore Laboratory (*EPRI Journal,* July/August 1978, p. 51).

One of the obvious drawbacks of the direct Charpy fracture toughness correlations is that the Charpy energy versus temperature relationship is assumed to be identical to the fracture toughness versus temperature relationship. One way to circumvent this limitation is being developed under EPRI funding: to analyze statistically the complete fracture toughness versus temperature relationship for a number of heats of typical reactor vessel material. The toughness data are fitted to a function (hyperbolic tangent) that represents the physical behavior. Charpy data from the same heats are then statistically analyzed by converting the Charpy energy into the appropriate units of toughness. With accepted statistical procedures, conversion factors are generated to transform the coefficients of the Charpy fit to corresponding coefficients for a fracture toughness curve estimate.

The fracture toughness–temperature response of the vessel material can be estimated statistically from the measured Charpy transition curve and the conversion factors developed. Conversion factors are available to develop average toughness estimates, as well as to develop statistical bounds (either confidence or tolerance) on the estimated fracture toughness. An example of the procedure is shown in Figure 2, which illustrates the predicted fracture toughness and compares it with actual measurements of the toughness for that material.

Figure 2 Schematic for the fracture toughness estimation scheme. Charpy impact data are fitted with an analytic function **(a)** and corresponding coefficients are determined (A, B, T_0, C). These coefficients are adjusted **(b)** by statistical functions developed in this research. These adjusted coefficients then describe an estimated fracture toughness curve **(c)** for the same material. Actual fracture toughness data are plotted to indicate the accuracy of the estimated curve. The curve indicated in **(c)** is a tolerance bound (limit) indicating that with 90% confidence, 90% of the fracture toughness data lie above the curve.



This procedure is being evaluated by a technical industry committee responsible for the development of improved reference toughness curves for the ASME flaw evaluation procedures. Work is also progressing to assess this method for the prediction of fracture toughness for irradiated materials from irradiated Charpy impact data. *Project Manager: Theodore Marston*

R&D Status Report
ELECTRICAL SYSTEMS DIVISION

John J. Dougherty, Director

OVERHEAD TRANSMISSION

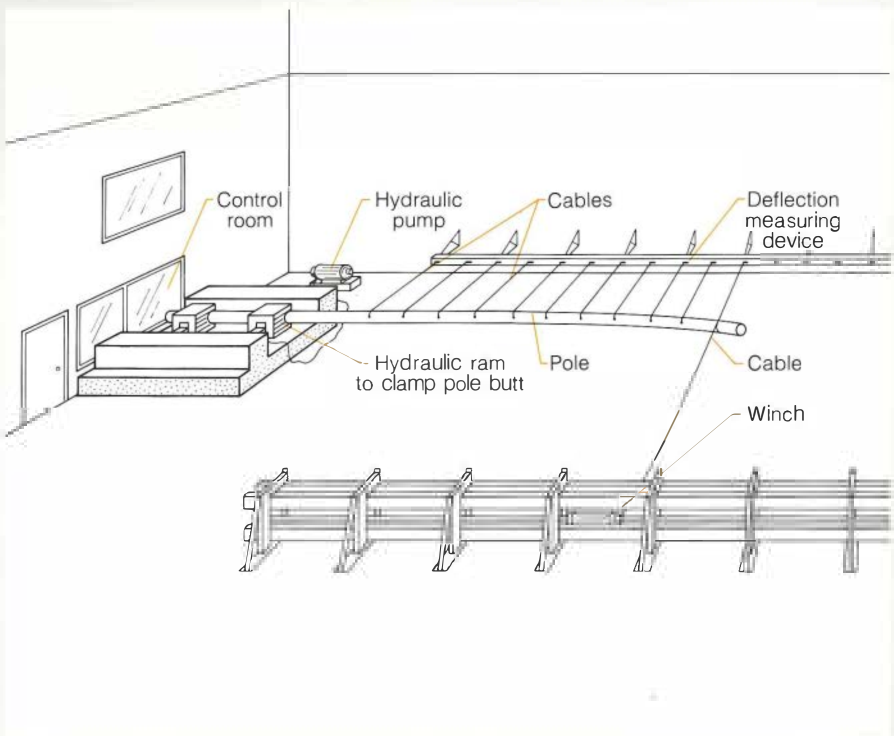
Wood structure design

The use of wood in the design and construction of transmission line structural systems continues to provide an attractive solution to the continually rising cost of transmission lines. In the past, wood pole construction has generally been limited to distribution and low-voltage transmission, but today wood is being considered as a viable alternative for structures carrying lines up to 765 kV.

Some of the characteristics that make wood attractive include its high strength-to-weight ratio, the relatively simple tools required for construction, and the simple foundations required. Esthetically, wood structures are uncluttered and present a low profile. Because it is a natural material, wood is accepted by the public more easily than other construction materials.

In spite of these attributes, a number of questions on the strength and service life of wood structures need to be answered. In a wood pole design project (RP1352), Colorado State University Research Institute will study these questions and develop an improved design that will ensure a more consistent level of structural reliability (Figure 1). Substantial economic benefit to utilities should result from this research. Recommendations for a more rational method of pole selection, reduced maintenance, and the elimination of possible service outages due to structural failures can be expected.

Figure 1 Full-scale destructive tests are being run on wood poles at Colorado State University Research Institute to determine the reduction of pole strength with time in service.



Because wood is a natural material, there is a relatively high variation in inherent strength and rigidity, not only between poles made from different species but also between those from the same tree species. Once a pole has been placed in service, environmental conditions influence the deterioration of the pole's strength with time. Of these conditions, relative humidity and soil moisture are the most detrimental. Their effects must be taken into account, both as a function of time and of species used, in developing an improved design concept.

Current design methods use ultimate fiber-stress values of wood for calculation of service-life pole strength. However, a relatively high safety factor (generally 4) is incorporated to offset such qualities as the natural variability of the material. The fiber-stress values for each species of wood are generally taken from the ANSI 05.1 Specification, whose recommended values have been adopted by the National Electric Safety Code.

Recently, a great deal of concern has been expressed about the recommended values of ultimate fiber stress. Results of recent research projects on lumber indicate that the true fiber-stress values may be markedly lower than those recommended. As part of this research, several thousand full-size pieces of lumber were tested to destruction. The resultant ultimate fiber-stress values were then compared with those derived through ASTM procedures, which generally had been derived from tests of "small clear specimens." This comparison indicated a substantial reduction in fiber stress that to some extent can be attributed to the differences between original (virgin) growth timber and fast-grown (second growth) trees. These test results may have a significant impact on the future of wood pole design and construction throughout the electric utility industry.

In an attempt to determine if these findings indicate the available fiber stress in full-size poles, a search was made of all available data from pole tests. This was undertaken with the help of a number of pole suppliers, the USDA Forest Products Laboratory, and the Western Forest Products Laboratory of Canada. Of the 3000 full-scale pole tests that were run, all were on new poles, and of these, only 15 were on transmission-size poles greater than 55 ft (17 m) in length; all 15 were made from the same species. These limited data made it evident that a full-scale pole-testing effort might be needed to answer outstanding questions.

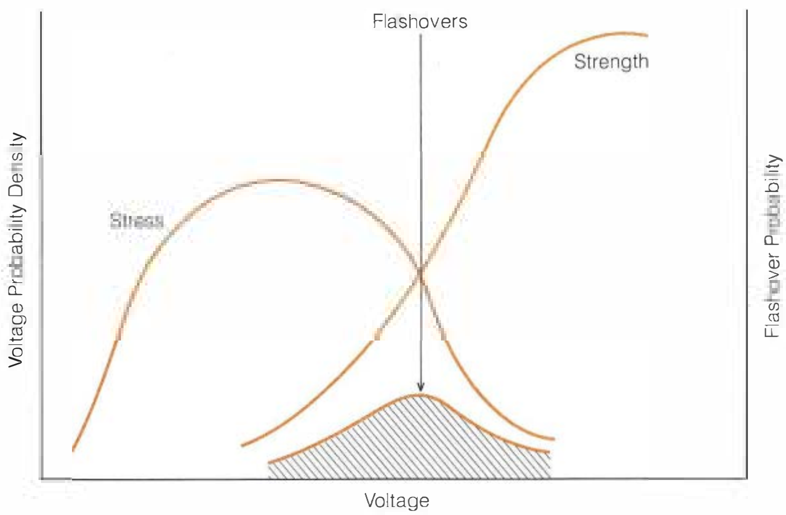
Before a meaningful pole-testing effort could be undertaken, an evaluation had to be made of the programs that would provide utilities the most usable information in the shortest possible time. It was found that the primary concern of utility designers is not just the strength of new poles, but how that strength varies over the service life of the poles. Since this strength reduction is directly affected by species, treatment, and environmental conditions, each utility service area presents a different set of parameters and must be considered individually.

To provide a rapid evaluation of the strength of poles in each service area, utilities will be asked to supply poles for testing. The test poles should have been in service for various amounts of time so that the reduction of strength with time in service can be quantified (poles removed from service because of extreme deterioration will not be used in the test). Results will be communicated immediately to the utilities involved and will also be combined to determine a geographic distribution of pole strengths and deterioration with time. Nondestructive testing methods for poles in service will be explored for correlation with the full-scale test methods and, if successful, will give utilities alternative methods for grading new poles before installation and methods of correlating the strength of poles in the field with the results of the laboratory tests. Consequently, utilities will be able to better ascertain the amount of service life remaining in any pole.

Pilot testing has begun, as described above, with the cooperation of several utilities. Depending on results, much broader pole-testing may be undertaken.

Before line designers can make full use of the information acquired in these tests, an improved design methodology must be developed. Probability-based designs will be used as the format for developing this methodology. This statistical approach is comparable with other utility designs, such as electrical insulation protection for transmission line systems. Predictions of insulation performance are based on a statistical analysis of a large number of flashover tests. Frequency distributions of stresses (e.g., lightning and switching-surge stresses) and insulation strengths are generated from these tests, which are then compared to predict the number of flashovers that can be anticipated (Figure 2). As in the case of electrical insulation performance, a number of tests must be run on wood poles to determine the frequency distribution for strength. However, the problem is more complex with wood than with insulation. Unlike electrical stresses, the frequency distributions for structural design loads (e.g., wind, ice, broken conductors) are not well defined. Also, estimates of wood strength over the long term become difficult with the addition of another dimension: wood's loss of strength with time (Figure 3).

Figure 2 Frequency distribution of electrical insulation performance can be related to the frequency distribution of structural design loads and wood pole strength. A large number of tests must be run to get equivalent data for wood poles from which probability-based designs can be derived.



This probability-based design approach is under study throughout the field of structural design. Probability-based methods are also being developed for use in the design of steel structures through the American Iron and Steel Institute and of concrete structures through the American Concrete Institute. The Canadian Standards Association has even gone so far as to mandate the use of probability-based design for all structures. The development of a probability-based design method as part of this project will bring the design of wood transmission structures to a level that is consistent with other parts of the industry. *Project Manager: Phillip Landers*

Project UHV

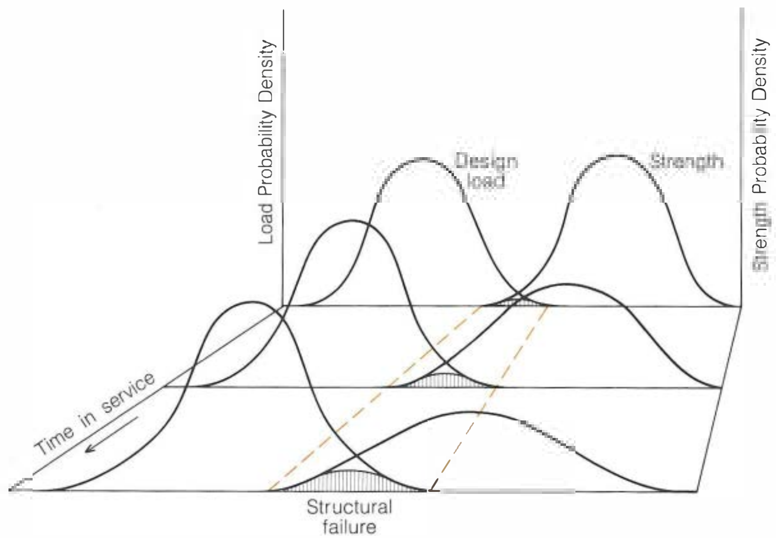
Project UHV was initiated by the Electric Research Council in 1967 to study overhead transmission lines with voltages greater than 1000 kV ac. Project UHV evolved from Project EHV, the research facility built and funded by General Electric Co. (1958–1964) to provide data for EHV transmission in the 400–750-kV range.

With support from the Edison Electric Institute (EEI) and the Tennessee Valley Authority in 1965 and 1966, Project EHV completed the study of EHV transmission and incorporated all available data in the *EHV Transmission Line Reference Book* published by EEI in 1968.

In 1967 the Electric Research Council, using funds provided by EEI and the Bonneville Power Administration (BPA), started a research program intended to cover a voltage range from 1000 to 1500 kV ac.

Instrumentation and equipment from Proj-

Figure 3 Frequency distribution of structural design loads and wood pole strength. Wood's uneven loss of strength over time adds a third dimension to the problem of predicting its stress capability at any given time.



ect EHV, already in place for research on EHV problems, were modified for the new research, and the project was renamed Project UHV in January 1967 to better describe its expanded activities.

In the early stages of this program, three-phase research was not justifiable from an economic point of view until single-phase work had defined the problems and assessed study priorities. Therefore, a single-phase test line was constructed and energized for the initial period of research, 1967–1971. The single-phase program was extended to 1973 when it became apparent that additional research was necessary to investigate further subjects of importance for UHV transmission, such as audible noise and electrostatic effects. In 1973 Project UHV was transferred to the sponsorship of EPRI, which has since published a new transmission design book that updates and extends the 1968 EHV reference book. The 1975 book, *Transmission Line Reference Book—345 kV and Above,* covers the electrical aspects of transmission line design from 345 kV to 1500 kV. The design data for UHV were obtained during the single-phase UHV program from 1967 to 1973.

Means for conversion to three-phase performance from single-phase test results had to be developed for each phenomenon being considered. Single-phase testing was limited by the fact that research for transmission above 1300 kV could not be effectively performed with the available single-phase equipment. For the same applied voltage, single-phase lines have conductor surface gradients that are 10–30% lower than three-phase lines.

To verify and extend the single-phase results, a three-year program to construct and operate a three-phase test line in the 1000–1500-kV range was started by EPRI in 1974.

New electrical equipment and structures were added to the single-phase facilities. The three-phase UHV test line was energized on January 25, 1975. The 1500-kV test capability makes the Project UHV test line the highest-voltage experimental three-phase line in the world. From February 1975 to December 1976, six different conductor and line configurations were tested on the three-phase test line at voltages between 1000 and 1300 kV. The electrical performance of each configuration was determined during long-term (3–5 months) exposure to natural weather conditions (EL-823).

In late 1976 it was decided to continue and expand the work until the end of 1979. More conductor sizes and configurations were scheduled for tests. Single-phase ac voltage capability was to be extended to the line-to-ground equivalent of 2000 kV. Line-to-ground and line-to-line switching surge capabilities were added and experiments were begun. This phase is expected to be completed on schedule in December 1979. By then five years' accumulation of data can be added to the reference book published in 1975, and in early 1980 a revised *Transmission Line Reference Book—345 kV and Above* will be published. This will complement work at the Bonneville Power Administration, American Electric Power Corp., and several foreign laboratories with whom we maintain liaison. By early 1980 planners and line designers will have most, if not all, the data they need for the design of lines up to 1200 kV.

Perhaps the most important research has been the measurement of environmental effects attributed to UHV transmission lines (EL-802). Most of the testing has determined the extent of audible noise, radio interference, TV interference, and ozone production from energized lines in all types of weather. All this information is available to researchers, designers, utilities, regulatory agencies, or anyone else interested in ensuring that transmission lines are environmentally acceptable. Although no biological research has been conducted at Project UHV, the information gathered is being used by biologists to design their experiments. When the time comes to build and operate UHV lines, a reliable base of information will be available.

Today, laboratory structures are huge and conductor systems are massive. Many mechanical problems will have to be solved before reliable and cost-effective UHV transmission becomes a reality. EPRI and other organizations will be expanding the efforts to solve mechanical design problems.

Because Project UHV is equipped and staffed for electrical research, it should be used to attack the major challenges facing the transmission of electric power, most of which lie in the area of dc transmission. Although dc transmission is still in its infancy compared with ac, its use to date has demonstrated great benefits. Two factors lead inexorably toward greater use of dc transmission: its inherent stability, coupled with the control function that it lends to large, interconnected ac systems; and its steadily decreasing cost relative to the cost of ac.

Because it is a young technology, dc transmission can benefit from the learning curve process in the same way as ac transmission progressed step by step through the EHV and UHV ranges. HVDC research is going through these same step sequences. BPA built a test laboratory to develop data for ±400-kV transmission; then, with EEI and the American Public Power Association (APPA), funded further work up to ±600 kV. The EEI and APPA funding responsibilities were taken over by EPRI in 1973. The research was completed in 1975 and a reference book, *Transmission Lines—HVDC to ± 600 kV*, was published.

EPRI has started laboratory research in Canada in the voltage range above ±600 kV. This project has already generated data that will serve as an information base for further research at Project UHV. A large dc power supply has been installed at Project UHV by DOE (Figure 4), and a companion supply will be installed by EPRI. Using both supplies, tests up to ±1500 kV will be possible. The line structures, contamination chamber, and much of the instrumentation that was put in place for ac research can be used for dc work as well.

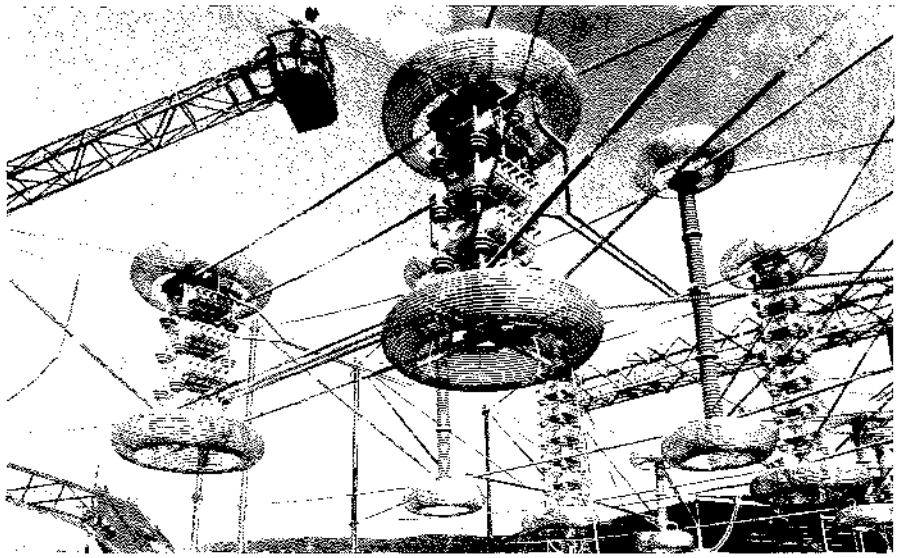


Figure 4 Worker installs finishing touches on dc power supply at Project UHV. This facility can now be connected ±750 kV or +1500 kV or −1550 kV.

In the next 20 years, the nation's electric utilities must build new transmission lines that are expected to cost $32 billion. The several millions of dollars spent at Project UHV will be repaid many times by savings in capital and irreplaceable resources. *Program Manager: Richard Kennon*

POWER SYSTEM PLANNING AND OPERATIONS

Economic operation of power systems

Continual changes in electric utility operating conditions require a periodic reevaluation of the methods used to improve economic operation. A major incentive for the recent reevaluation has been the continued rise in fuel prices.

The objective of the research described here is to reduce the cost of power system operations (and still retain acceptable system stability, security, and reliability) by improving

- System control performance
- Generation dispatch techniques
- Fuel scheduling coordination

First, key factors that affect the performance of member companies of an interconnected power system must be identified. This control performance analysis must be performed by each member or each control area of an interconnection.

Second, in evaluating generation dispatching methods, a contractor will examine the cost and feasibility of providing more timely data for the generation dispatchers. This contractor will also evaluate the impact of turbine-generator constraints on economic power system operation.

Third, coordinated long-term (yearly), mid-term (daily), and short-term (real-time) fuel scheduling will be developed.

Seven contractors have been conducting research for the past 18 months at a total funding of almost $2 million.

A 30-month, $327,000 control performance analysis is being conducted by the Energy Management Systems Division of Control Data Corp. and Northern States Power Co. (NSP) to develop criteria, guidelines, and working tools for evaluating the performance of a control area. Control Data is developing an analytic method to determine the cost of various system-operating criteria. A computer program will simulate the interaction of one control area with a larger network of control areas. The development of the simulation program has been completed and data from the NSP system are being used to determine the cost of changes in system-operating guidelines. Although these changes were introduced to improve system control performance, no method was previously available to determine the added cost or savings resulting from the changes (RP1048-1).

The simulator being used by Control Data was developed by Philadelphia Electric Co. (Peco) in a 16-month, $135,000 project (RP1048-4). A workshop on the use of the PEC simulator was held in Palo Alto, California, on May 1, 2, and 3, 1979. (This computer program is available from Technology Development Corp.; Leroy Krider, [408] 734-5500.)

One of the largest factors in economic performance is the change in the cost of generating at different levels of power output. As an adjunct to the Control Data research, a project with Power Technologies, Inc., was begun in February 1978. This is a 2-year, $199,000 project to develop analytic models of power plant components. Once these models are available, the cost of producing power at the different levels needed for automatic generation control can be determined (RP1048-2).

In a separate 30-month, $377,000 project, Peco is to develop improved generation dispatch techniques and will

- Examine improved methods of mathematically representing a turbine-generator used in economic generation dispatch
- Evaluate the impact of turbine-generator operating constraints on economic generation dispatch

Peco will evaluate the methods now used to determine and update turbine-generator input-output representations. The bulk of the work to date has involved the testing of three steam turbine-generators and two gas turbine-generators. The test plan calls for monthly tests of these five units for one year (RP1048-3).

Because coal is expected to be a major fuel in the next decade, Science Applications, Inc., conducted a four-month, $48,000 study to explore the feasibility of measuring the thermal content of coal suitable for use along power plant coal conveyor belts (RP1048-7).

In the third research area, two contractors will examine ways to improve coordinated fuel scheduling. In a 2-year, $214,000 project, Power Technologies is examining the daily fuel scheduling of the New York Power Pool.

Power Technologies developed an efficient computer program for daily fuel scheduling. The operating requirements considered include constraints on thermal units, such as unit minimum up- and downtimes; operating limits; response rates; limitation of fuel supply; operation of conventional hydro generation; a variety of reserve requirements; operation of pumped-storage hydro generation; and transfer limitations for multiarea operations (RP1048-5).

In a 3-year, $439,000 project, Boeing Computer Services, Inc., is developing computer programs for long-term (yearly), midterm (daily), and short-term (real-time) fuel scheduling (RP1048-6). *Project Manager: Charles Frank*

Advanced computer concepts

Research topics are sometimes requested from a broad audience. A solicitation to universities for beneficial and innovative research topics is the approach used in RP1355. The objective of this approach is to encourage and support studies that have significant potential within the scope of the Power System Planning and Operations Research Program. New analytic techniques for the advancement and application of modeling theory, control systems, large-systems concepts, and network theory are typical of the results expected from present and future projects.

At Northwestern University, researchers are investigating improved methods for the parallel solution of power system network equations (RP1355-1) and the relationship between computation efficiencies and the number of parallel digital processors. Various ways to prevent processor saturation are being evaluated. Alternative architectures are being investigated that will support the communication of information between the processors involved in the parallel solution of the network equations. The algorithms and techniques developed will be tested through simulation on a CDC 6600. Microprocessor and memory requirements will be analyzed to identify those that best serve the parallel algorithms developed.

The second project is with Cornell University and focuses on two topics (RP1355-2). The first is the application of an array processor (Floating Point Systems AP 120B) for solving ac power flows by using a modified fast decoupled approach. The second topic is to investigate how such a computation tool can support on-line contingency analysis in the power system dispatch center. Algorithms developed under this research are to be coded and evaluated on an AP 120B. The results obtained with the AP 120B will be compared with those obtained with conventional digital machines (e.g., IBM 370/158) and the EPRI hybrid computer. The results of this research and those of RP1355-1 will help determine the approaches that should be used for the application of parallel computing devices with power system software to solve power systems problems.

Iowa State University is concentrating on power system security assessment, the alert state (RP1355-3). While in the alert state, power system loads are assumed satisfied, with no serious overloads. However, the system condition, by definition, is such that some additional disturbances will place that system in the emergency state (lines overloaded or an underfrequency condition). The objectives of this study are to develop a working definition of the alert state, to define alert-state detection criteria and associated indexes, and to prepare the groundwork for remedial control. System conditions that are likely to place a power system in an alert state are under study as well. Sets of conditions that suggest the alert condition will be further evaluated by using power system analysis software (e.g., load flow and stability) and case histories of actual operations. Alert-state indexes are to be formulated and the remedial actions to recover from each alert condition are to be defined.

The University of Nebraska at Lincoln is to develop and validate a procedure for automatically building load forecasting models from load and weather data (RP1355-5). The load forecasting model resulting from the procedure will be evaluated, using historical data, and compared with other load forecasting methods. A model-building procedure will be of value to utility company engineers for defining and updating models used in load forecasting computer programs. When forecasted peak loads differ significantly from actual loads (while forecasted weather agrees with the actual weather), the utility engineers could exercise this procedure to update the model in their on-line load-forecasting program.

The scope of research in RP1355 will change as projects are completed and new ones are begun. *Project Manager: Donald Koenig*

SUBSTATIONS

Fault locators for gas-insulated substations

Dead-tank, gas-insulated equipment is becoming more accepted in EHV and UHV substations. Compactness, improved esthetics, freedom from electrostatic fields, and lower installed costs, especially at high voltages, are expected to increase the use of gas-insulated equipment even more. In spite of the availability of equipment rated through 500 kV, some unanswered questions remain about maintenance and servicing; for example, how to detect and repair faults in totally enclosed substation components.

General Electric Co. is developing techniques that will provide such information as location of the fault, extent of the damage, or, if possible, advance warning of incipient faults from telltale symptoms (e.g., internal corona) (RP1360-2). Fault detection sensors will be developed that could be installed within the gas or attached to the enclosure surface at appropriate locations along the length of the gas bus. Of the various concepts pursued, three now appear promising: chemical, optical, and magnetic sensors.

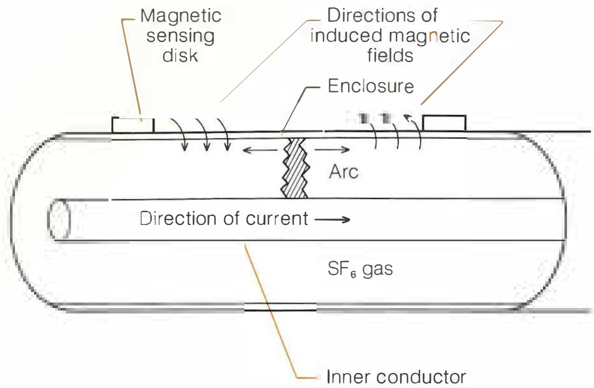
In the first, the reaction between a resistive film element and the arc by-products of a fault leads to a drastic change in film resistance. Results indicate that thin-film sensors made from organic polymers appear to have the required sensitivity and are capable of reverting to their original resistance value, eliminating the need for replacement. There are several other materials being investigated for this application, of which tin oxide holds the most promise.

In the second approach, photo diodes are used that result in an inexpensive sensor design capable of registering a fault instantaneously. A sensor like this may be sensitive enough to detect corona and provide information on incipient faults.

The third approach to sensing faults depends on the unbalanced magnetic fields associated with fault currents. The flashover between the conductor and the enclosure results in magnetic field concentrations of sufficient magnitude to permanently magnetize the sensing disks applied on the surface of the enclosure (Figure 5). Although this approach can only detect actual faults (because it is insensitive to incipient faults), it can be applied on existing installations without taking the equipment out of service.

Ontario Hydro's Electrical Research Department is developing fault detection schemes that can be retrofitted on existing equipment (RP1360-1). Two different but equally promising detection schemes have

Figure 5 Cross section of a gas-insulated system, showing the magnetic field that results from an arc between the conductor and the enclosure.



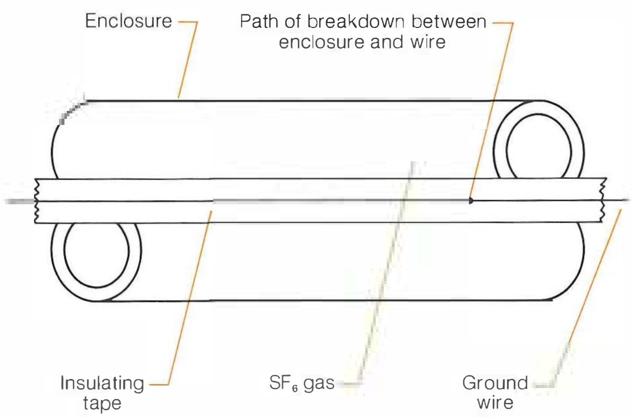


Figure 6 Insulating tape and ground wire combination fault detector, which is applied along the length of the gas bus enclosure.

been tried. In one, an insulating tape is applied along the length of the gas bus enclosure, which has an independent ground wire running along the length of the tape. The arrangement (Figure 6) involves dielectric breakdown of the tape at the fault location, which is caused by the fault-induced transient rise in potential of the enclosure. While the potential of the enclosure is expected to rise at the instant of the fault, the ground wire remains essentially at true ground potential. This results in a dielectric stress across the insulating tape, causing a breakdown at the specific location of the fault. This method does not give information on the severity of the fault. However, the detection method is versatile enough to detect low-current flashovers, even during dielectric tests.

Another method, which should be capable of assessing the damage within the bus, employs an infrared monitoring system. Since this system is sensitive to changes in the enclosure temperature, it is expected to indicate not only the location of fault initiation, but the subsequent range of the arc in the event the arc travels down the length of the enclosure. Experiments have related various arc conditions and the enclosure's temperature rise to damage within the gas bus. This detection scheme is expected to result in a comprehensive method of locating and assessing the consequences of faults. *Project Manager: Vasu Tahiliani*

Light-fired thyristors

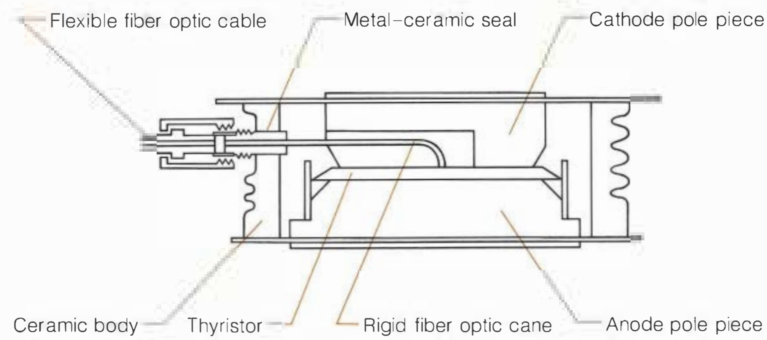
Electrically fired thyristors have proved their worth in the power transmission field, both in HVDC rectifier/converter valves and in the generation and smooth, instantaneous control of reactive power. The electrical triggering system of the thyristor is open to improvements, however, because it requires either insulation above ground potential or powering of the trigger circuits from a voltage divider off the power line being controlled. This, of course, means that when the line voltage is low and most in need of reactive support, the triggering circuits may well be below their safe minimum operating level. In any case, such an approach requires many electronic components at each thyristor level, which reflects unfavorably on the reliability of the valves.

Light-fired thyristors eliminate the gate insulation problem, or rather, absorb it, since the triggering signal is carried from ground potential to the thyristor gate by a glass fiber, which in itself is an excellent insulator. It also provides immunity to electromagnetic noise found in areas where thyristors are normally used. EPRI is supporting light-fired thyristor projects with General Electric Co. (RP669) and Westinghouse Electric Corp. (RP567). In the General Electric project, extensive computer modeling is aimed at developing light-fired thyristors for HVDC valves where anode voltage, dv/dt, and di/dt are important. The General Electric light-triggered thyristor eventually will be incorporated in an advanced valve for HVDC with higher current and voltage capabilities, aided in part by larger-diameter devices, internal self-protection, and improved heat transfer (both internal and external).

Westinghouse has been working toward incorporation of a light-fired thyristor switch in one phase of a static VAR generator under extended test at Minnesota Power and Light Co. A switch module has been designed, and Westinghouse is fabricating the light-fired thyristor switch, which will be installed at MP&L late this summer.

Both projects are developing improved, redundant light-delivery systems where multiple laser diode sources feed fiber optic cables, which in turn carry the light signal to a number of thyristors. The fiber optic cables are randomized to enhance reliability. The light used to trigger each of the thyristors comes from a number of laser diodes. This system is designed so that enough light is available to fire each thyristor in the string, even if several of the laser diodes fail simultaneously. Maintenance is also simplified because light sources at ground potential can be replaced without shutdown of the switch module itself. Two different means of bringing the light pulse into the thyristor package are shown in Figures 7 and 8. Success in these light-fired thyristor projects will enhance and expand the solid position that semiconductors have already attained in the growing HVDC area and in the stabilization of the reactive power flows in the ac systems. *Program Manager: Narain Hingorani; Project Manager: Gilbert Addis*

Figure 7 Radial-entry, light-fired thyristor. Light pulse from flexible fiber optic cable is coupled to internal, rigid fiber optic cane.



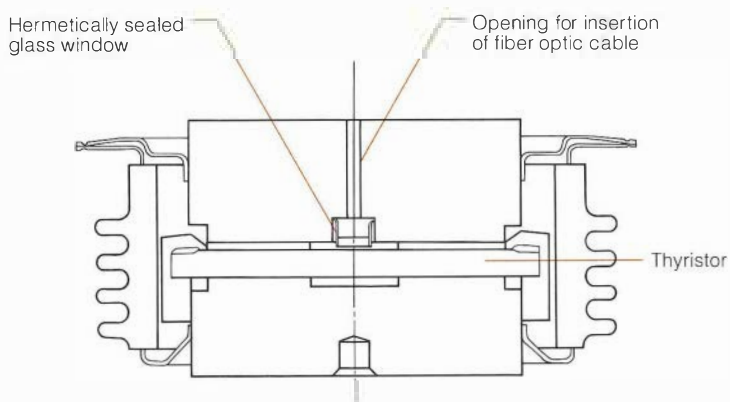


Figure 8 Axial-entry, light-fired thyristor. Flexible fiber optic cable transmits the light pulse through a glass window directly onto the thyristor.

DISTRIBUTION

Optimized concentric neutrals for extruded URD cable

A hundred years ago Edison was installing jute- and compound-insulated copper rods in iron pipes to distribute dc electric power out of sight—underground. To perform the same function today, materials and practices are used that Edison would not recognize but would surely appreciate.

Closely following the introduction of the Edison tube system was a period of rapid development in underground cables to meet the needs of increasing load densities and the acceptance of ac. This development quickly centered on cable composed of copper conductors that were insulated with rubber or dielectric-fluid-impregnated paper and protected by lead outer sheaths.

These materials remained the standard cable components for the next 50 years. Substantial improvements in the state of the art of using these components occurred in the interim, but there was no truly new cable until the advent of aluminum-conductor, solid-polyethylene-insulated cable with copper wire concentric neutral in the 1950s.

This cable appeared at the time when great pressures were being exerted on utilities to improve the appearance of distribution facilities by going underground. Less expensive than the traditional cable, the easy-to-handle, solid-dielectric, concentric-neutral cable was widely accepted and was soon being installed in great quantities. Thus, it did not have the opportunity to pass through important introductory and long-term aging phases when performance could be observed and designs could be refined.

In conformity with accepted practices, design of the new cable was conservative. But the components were new and little detailed knowledge of their long-term performance characteristics had been achieved. Cable is particularly sensitive to thermal damage, so the thermal design was established, using existing, conservative concepts. These concepts were valid for certain early cable designs but not necessarily for the new cables with copper-wire concentric neutrals.

To verify practices used in the design of concentric neutrals, a contract was negotiated with Pirelli Cable Corp. to develop a method of determining optimal neutral design (RP1286.). The project was undertaken in view of independent research performed in the past few years, which indicated that some cables as presently constructed have over-designed neutrals.

In this project the contractor will develop an analytic transient temperature-rise model for typical underground residential distribution (URD) cables of both round-wire and flat-strap neutral construction. This model will be capable of predicting the transient temperature of cables during short-circuit conditions.

Cables representative of commonly used combinations of insulating material, neutral construction, and jacket construction will be manufactured and short-circuit-tested to measure the transient temperature characteristics and to determine the damage threshold. Unjacketed cables and cables jacketed with typical materials will be used. Similar tests will be performed on aged cables that have been removed from service.

The results of additional tests on laboratory-scale models, together with the data from the full-scale tests, will be used to verify, and modify if necessary, the mathematical model. The model will then be available to predict the thermal performance of cable with any construction. *Project Manager: Herbert Songster*

UNDERGROUND TRANSMISSION

Extruded cable systems

Prototype extruded 138-kV and 230-kV cables developed by General Cable Corp. have successfully completed long-term laboratory tests (RP7829). Samples of these cables are installed at two utility sites for field tests. Work is continuing on the development of joints and terminals especially suited to these high-stress cable designs.

Pirelli Cable Corp. wishes to purchase and commercialize the special compound purification and cable extrusion system developed in this project. EPRI and Pirelli are negotiating a purchase agreement.

Two interim reports on this project have been published. One deals with the development of the compound purification and cable extrusion system, and with 69-kV model cable tests (EL-428). The other is a state-of-the-art report on dynamic modeling for computer control of extrusion systems (EL-605). *Project Manager: Felipe Garcia*

Pipe-type cable service

A new project to investigate thermomechanical bending of pipe-type cables will be jointly funded by Empire State Electric Energy Research Corp. (Eseerco) and EPRI (RP7873). Funding for the five-year contract is $1,800,000, two-thirds of which will be provided by EPRI and one-third by Eseerco. The objectives are to further establish the reliability and service performance of EHV pipe-type cables for underground power transmission.

Since first placed in commercial service in the 1930s, pipe-type cable systems for underground transmission have performed with exceptional reliability and trouble-free service; some 3000 circuit miles are installed at voltages ranging from 69 kV through 345 kV.

Over the last five years, service problems on 345-kV cables and investigations at Waltz Mill on 550-kV cables have led engineers to suspect possible mechanical instability in the cable's insulation structure under cyclic expansion and bending. For these cable designs, large conductors and a substantial number of insulating tapes (ranging from 175 to 250 layers) are required. The high dielectric strength and the electrical integrity of the insulation depend on maintaining the precise taping structure throughout. Localized mechanical instability or disarray of the insulating tapes during thermomechanical expansion and repeated bending could decrease the electric strength and service life of the insulation.

The project will provide a thorough understanding of the basic principles of thermomechanical behavior of EHV pipe-type cables. Theoretical analysis of cable bending and insulation behavior will be combined with tests on selected cable configurations. Tests will include mechanical flexure tests to simulate bending and to separate the interdependency of variables. Thermal expansion tests (heating cable conductors in line pipe) will be correlated with observation of insulation structure behavior under repeated bending. New cable designs and prototypes will be evolved from this analysis, tested in mechanical flexure and thermal expansion, and tested electrically, if necessary, to ascertain full compatibility. *Project Manager: Stephen Kozak*

Increased pipe-type cable section lengths

Over the last several decades, conservative practices have generally been followed in the calculation of pipe-type cable-pulling tensions and insulation sidewall pressures. As cable system voltages have increased and labor costs have escalated, pulling and jointing costs have proportionately risen to the point where making longer pulls, consistent with high reliability, makes good economic sense. Although the incentive for maximizing pulling lengths exists, reliable data on the stresses that might be encountered do not.

The industry's continuing interest in the various technical aspects of cable pulling has been very evident. Industry reports, particularly from the IEEE Insulated Conductors Committee, have shown that there are apparent advantages to the use of certain materials and practices in cable pulling. However, the accumulated data have been contradictory at times and, at best, inadequate to form a sound basis for reliable recommendations to the industry.

Users, cable manufacturers, and installers have expressed willingness to help gather accurate cable-pulling data. However, the efficient accomplishment of the work required a well-planned program and appropriate funding. Therefore, EPRI has funded a project with Power Technologies, Inc., to establish a sound scientific and engineering base for longer section lengths (RP7847). The major tasks in this research involve establishment of friction factors, permissible sidewall pressure and pulling tensions, and performance standards for commercial pulling bolts. Laboratory tests are being supplemented with field verification demonstration pulls on actual cable installations of Potomac Electric Power Co. and possibly Long Island Lighting Co.

Tentative conclusions indicate that stainless steel skid wires show a distinct advantage with friction factors in the range of 0.10 to 0.12 versus 0.17 to 0.24 for bronze and zinc. Sidewall pressures (800–1000 lb/ft of radius; 1.2–1.5 Mg/m of radius) caused no significant tape disarray or damage. The present 52.6 MPa (6 lbf/kcmil) pulling tension design value used for design purposes for aluminum conductors is probably limiting. The 70.2 MPa (8 lbf/kcmil) figure used for copper conductors is conservative and 87.7 MPa (10 lbf/kcmil) might be considered. Most mechanical pulling bolts did not approach the full strength of the conductor, but reverse-tapered cup attachments performed well. Additional field corroboration of these tentative conclusions is under way. Implementation of these conclusions after corroboration will result in cost savings because of the reduced number of pulls, manholes, and joints, and will afford increased flexibility in locating manholes. *Project Manager: John Shimshock*

R&D Status Report
ENERGY ANALYSIS AND ENVIRONMENT DIVISION

René Malès, Director

SHOULD EPRI HAVE AN OCCUPATIONAL HEALTH PROGRAM?

Until recently, the answer to the question posed by the title of this article was no. It was neither a resounding no nor a deliberate policy, but a matter that seemed to have low priority among the pressing problems of the day. Occupational health issues of the utility industry had a fairly low profile in 1973, the year EPRI went into operation. However, since then interest has grown and there is now reason to reassess that unwritten policy.

There are those within the industry who perceive a rising level of national concern regarding this backwater of health research and who foresee that the utility industry will be caught in the crunch of regulatory constraint and union pressure. They point to already rising costs for their medical programs, insurance coverage, compensation, and regulatory compliance.

Others disagree. They argue that fostering research on problems of occupational health will only create exaggerated fears of illness or hazard, which will in turn generate unjustified demands and costs. Who is right? We will first consider a bird's-eye view of occupational health in the utility industry, with examples of existing areas for concern, and second, an overview of some EPRI plans for addressing these problems.

That certain occupations are associated with toxic exposure and illness has been known for hundreds of years. In the eighteenth century an Italian physician, Ramazzini, provided an accurate clinical description of the symptoms of mercury toxicosis among the potters of Florence. During the same period, the English surgeon Sir Percivall Pott identified an increased risk of scrotal cancer among chimney sweeps and recommended improvements in personal hygiene as an effective preventative. Nowadays, employees who are exposed to cotton dust, asbestos, coke ovens, certain metals, and many other industrial agents suffer greater risks associated with those occupations.

Hundreds of such associations between industrial practices and illness are now recognized, and measures for the prevention or minimization of these effects have been widely instituted. These efforts have been largely successful, and experience, although often poorly documented, appears to demonstrate a long-term decline in morbidity and mortality among industrial populations. Nevertheless, in the early 1970s Congress mandated increased research into industrial health. To implement this effort, the Occupational Safety and Health Administration (OSHA) was created within the Department of Labor, and OSHA's research arm, the National Institute of Occupational Safety and Health (NIOSH), was formed within the Department of Health, Education, and Welfare.

What are some occupational health problems in the utility industry? The one that receives the most attention in executive board rooms is ionizing radiation, as experienced in nuclear reactor operations. To those who have followed the public debate on nuclear power over the past several years, it comes as something of a surprise to find attention again focused on low-level radiation, the issue on which pro- and antinuclear forces first differed at least a decade ago. The issue then fell into relative obscurity as questions of nuclear waste, safety, and other issues surfaced. With little doubt, responsibility for this renewed interest lies with the publication in 1977 of Thomas Mancuso's studies of mortality among some 23,000 workers employed since 1944 at Hanford, Washington. He and his coworkers concluded that occupational radiation exposure had resulted in an increased cancer mortality in this population. The magnitude of this effect was many times greater than would have been predicted on the basis of known estimates of radiation risk. This cast doubt on the legitimacy of the conclusions of the National Academy of Sciences and other radiation protection agencies whose studies had been based largely on high-dose exposures.

The Mancuso findings have not gone unchallenged. A large number of critics have attacked the Mancuso report for its methodology and conclusions. Nevertheless, federal interest in possible effects of occupational radiation exposure is now intense. Because utility employees have a large aggregate exposure to ionizing radiation, efforts are already under way at the Nuclear Regulatory Commission (NRC) to undertake a study of health among these employees, although the design and extent of the study are not yet clear. Based on the relatively low annual average radiation exposures received by this group, no detectable effects would be anticipated. Still, it seems inevitable that pressure will increase for such a study.

Until recently, only a very few chemical agents were known to be human carcinogens. With the exception of those found in cigarette smoke, most of these agents have been identified from studies of occupational exposure. These include asbestos, vinyl chloride, certain metals (such as nickel), and notably, coal products. More recently, the development and use of certain rapid screening tests, based on the known mutagenic properties of carcinogenic agents, have brought suspicion on many industrial agents, drugs, and foods as possible carcinogens. These widely reported developments have produced a heightened public concern about cancer that will almost certainly focus on the workplace, where exposures are usually the most intense.

OSHA policy on permissible exposures to potential carcinogens is only now being formulated but will undoubtedly have significant repercussions for industry. Since many coal-derived materials are known to be carcinogenic, the possibility of the use of coal products in the utility industry is certain to be affected by these developments. In fact, a report has already appeared suggesting that DOE decisions on further funding of solvent-refined coal development will be strongly influenced by studies of the cancer risk among workers in an industrial environment.

Anyone who has visited a utility steam station is aware of the level of noise. The very nature of this technology, which requires the use of large fans and turbines, creates a distinctive high-pitched sound. Several utility engineers have been working for years to find ways to suppress these sources of noise and mitigate their effects on both the people working in these facilities and those living nearby. So far, OSHA has not been vigorous in enforcing permissible noise levels, so little is yet known of the impact of noise regulations on utility operations or on the extent of hearing loss, if any, among utility employees.

Newly developing research, particularly in Europe, suggests that noise exposure may have health effects other than on hearing alone. If such reports should be substantiated, pressure to enforce and strengthen noise exposure limits would undoubtedly grow. Are those noise exposure limits adequately designed to optimally protect hearing in the most cost-effective way? Many utility people think not, yet research on this question has not yet provided definitive answers.

Unlike noise, which is virtually ubiquitous in all industries, exposure to high-strength electric fields is most widely found in the utility industry, principally among high-voltage linemen and switchyard workers. Information on health effects of such exposures is still fragmentary and often conflicting. Studies of occupationally exposed linemen in the Soviet Union are said to have demonstrated an increased frequency of nonspecific symptoms among such persons. These studies, however, are viewed with some skepticism and could not be replicated by Swedish, Canadian, or U.S. investigators. Nevertheless, public attention to the health effects of high-voltage transmission lines is rapidly increasing. Although EPRI has undertaken an extensive research program into possible effects of electric fields on animals and plants, studies of exposed humans have not yet been undertaken.

The issues raised above are not meant to be a comprehensive survey of occupational health problems in the utility industry. They are more in the nature of a sampler and ignore a number of problems obvious to those actively working in the field. In an industry whose employees are outdoors, summer and winter, working on towers, underground, in boilers, in high-radiation environments, and with hundreds of different chemical agents, potential problems range from the prosaic to the exotic. The recent recognition of Legionnaire's disease as the cause of the illness that hospitalized eight men in 1973 after they had cleaned a condenser is an example of the latter.

The utility industry is not assumed to be a particularly hazardous place to work. On the contrary, it appears to be a relatively benign industry, which may to a large extent be the result of ambitious safety programs mounted by a large number of utilities and pursued by a large number of competent and dedicated people. The point is that the utility industry has high visibility. Comparisons with other more hazardous industries are not likely to be persuasive, and until more information is available on the extent of health and safety in the utility industry, we cannot be complacent.

What is EPRI doing to provide the needed information? A number of projects have already begun. Others are still in the conceptual stage. For example, an EPRI-wide noise mitigation program is being planned. An investigation of carcinogenesis that is probably more ambitious than that of any other industry is already in place. RFPs have already been circulated to solicit work on the epidemiology of high-strength electric fields. In this research, an electric-field dosimeter developed for EPRI by General Electric Co. will be used. Another RFP is directed toward a feasibility study of a health registry, envisioned as an ongoing survey of health among utility workers, including those exposed to ionizing radiation.

The need for an occupational health program at EPRI seems established on a number of grounds. At the same time, it is recognized that this program should not arouse exaggerated concerns. It is our hope that carefully planned research, the objectives of which are well understood by all parties concerned, will be a useful contribution to the employees of the utility industry and to the industry itself, which is responsible for maintaining a healthy working environment. *Program Manager: Leonard Sagan*

ENERGY MODELING FORUM

The Energy Modeling Forum (EMF) was created to improve the practical use of energy models in analyzing policy issues and in planning (RP875). Administered by the Stanford University Institute for Energy Studies, EMF operates through a series of working groups of energy model developers and users who make comparative tests of a variety of energy models. Different models are examined in the context of an important energy decision, such as forecasting the demand for electricity under time-of-use pricing.

During the past few years, several computer-based models of energy-economy systems have been in various stages of development and implementation. These models have the potential of providing important insights into many complex economic and environmental interactions that affect the electric utility industry. The models could provide better information to decision makers on a broad range of questions related to energy supply, demand, and distribution. Full realization of this potential, however, requires effective interaction between the decision maker and the model builder.

In the energy-modeling field today, greater attention goes to building and extending models than to analyzing and understanding them. Thus, a reasoned evaluation and constructive criticism of models for the benefit of decision makers and model users is lacking. This deficiency breaks the chain of model development and application, a chain that offers a major opportunity for the effective use of analytic tools to evaluate energy options.

Members of the EMF working groups are drawn from many parts of the country and the energy field, and include experts in engineering, economics, and systems analysis. Assisted by the forum staff, they meet periodically to plan and discuss the results of model runs. Group chairmen serve on a rotation basis. A typical group consists of perhaps 10 model developers, 5 model users from the energy industries, 3 model users from the government, 3 from EPRI, and 5 participants with other backgrounds, as appropriate. Stanford University serves as administrative headquarters for the EMF staff.

Following a 1976 summer workshop, the project was initiated with a first study designed to demonstrate the forum research concept. The first EMF working group studied models that link energy growth and economic growth. Six models were compared in order to isolate the key factors that tie the energy system to the long-run growth of the economy. The results demonstrated the importance of the value share of energy in the economy (currently, the value of energy as a proportion of GNP is about 8%), the flexibility of energy use, and the link between productivity and capital formation. The working group's report breaks new ground in explaining the behavior of the models, in clarifying the use of the models, and in identifying new areas for model research (EA-620).

During the spring of 1977, a senior advisory panel, chaired by Charles Hitch of Resources for the Future, Inc., and including several senior utility executives, was set up to guide the EMF project and to help communicate the results to the energy policymaking community. The panel makes recommendations regarding future EMF studies, assists in the selection of working group chairmen and members, and evaluates the ongoing efforts of the working groups.

A second EMF working group was organized in July 1977 to examine the topic Coal in Transition: 1980–2000. It was chaired by David Sternlight of Atlantic Richfield Co. As in the first study, tests of the models were made and the common results or the causes of any model differences were explained. The conclusions relevant to the electric utility industry include the following.

- The total demand for coal will rise substantially over the next 20 years, given the study's assumed rise in the price of oil and gas and the assumed level of nuclear power generation. Under these conditions, there is a strong economic advantage in the use of coal rather than oil and gas in all new baseload electricity generation and many industrial fuel choices. This occurs even in the presence of environmental standards as strict as the use of Best Available Control Technology.

- More stringent environmental standards increase the cost of coal use, as would be expected. However, there is little difference in coal production patterns and cost between tightening emission standards to either one-half the New Source Performance Standards or the Best Available Control Technology. In both cases, these changes in standards impose costs in the range of a few billion dollars per year by 1985 on coal use, compared with the reference case.

The comparison of different approaches to modeling electricity consumption was the focus of a third working group chaired by Bernard Cherry of General Public Utilities Service Corp. This study differed significantly from previous model comparison studies because it involved 10 models with different geographic coverage. Most of these models are used to develop load forecasts for particular utilities and therefore are applicable only to each utility's service area. This created difficulties in standardizing the models' inputs, but the problem was minimized by specifying input parameter variations among scenarios in percentage terms and by requiring the participants also to report variations in output variables in percentage terms.

The working group found that the models relied, to various degrees, on two forecasting techniques—econometric and engineering (or end-use). Both techniques provide insight for forecasting loads. Based on modeling results and their discussions, the working group concluded that future electricity growth rates are likely to be lower than in the past. The comparative model runs showed that the forecasted impact of the prices of electricity and other fuels on the use of electricity differed widely among the models. The group felt that better estimates of the magnitude of such impact may be extremely important if future prices are expected to differ significantly from historical prices. The estimated magnitude of the impact tends to vary directly with the size of the region over which the estimates are obtained. The use of data combined from many regions (time series–cross section) produced much larger estimates of price responsiveness than when data were obtained from a single region (time series). The debate over the proper source and use of such data is an important unresolved issue in forecasting. Using the models, the group also examined efficiency standards and time-of-day pricing. These can have a significant impact on load shape and load factor and, consequently, on capacity-planning decisions.

The third working group recommended that work should proceed toward either the parallel pursuit or the integration of econometric and engineering load-forecasting techniques and that models should attempt to incorporate explicit forecasts of load shape as well as the level of kilowatt and kilowatthour demand. More generally, the working group's consensus was that an annual meeting should be held to investigate load-forecasting issues and to report on the results of further comparative model studies. The group stressed that comparative studies, such as those by EMF, build effective communication bridges between energy decision makers and modelers. The report *Electricity Load Forecasting: Probing the Issues with Models* will be published later this year.

Partly because EMF's first report had identified one factor—elasticity—as a crucial determinant of the strength of the link between energy and the economy, EMF's senior advisory panel recommended that EMF perform further experiments to improve the precision and level of confidence in such elasticity estimates. During early 1978, the EMF staff, with the aid of many outside experts, designed an experiment to estimate the aggregate demand elasticity in an energy model. By August 1978, the experiment had been run on 17 models. Interest in the fourth study's results had risen to the point where a face-to-face meeting of its participants, headed by William W. Hogan, and interested observers seemed desirable. Consequently, a working group of approximately 40 people, predominantly model builders, met in October 1978 to discuss results of these model runs. The report on this fourth study is also expected to be ready for publication this year.

The fifth EMF study, just starting, will investigate the degree of supply responsiveness to price changes inherent in models of the U.S. domestic oil and gas industries. Ben Ball, former vice president of Gulf Oil Corp. and now adjunct professor of engineering management at the MIT Energy Laboratory, is chairman of this working group. The group members have been selected and the first meeting was held in January 1979. *Project Manager: Stephen Peck*

New Contracts

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
Fossil Fuel and Advanced Systems Division				
RP109-6	Economic Assessment and Comparison of Alternative Beta Alumina Electrolytes	1 year	119.7	Laboratoires de Marcoussis (France) *J. Birk*
RP252-3	Improved Beta Alumina Electrolytes for Advanced Storage Batteries	18 months	96.1	University of California at Berkeley *K. Kinsman*
RP370-17	Reliability and Statistics Support for Advanced Battery Developers	13 months	59.3	Science Applications, Inc. *W. Spindler*
RP629-4	Laboratory Method to Simulate Utility Boiler Fly Ash	13 months	228.9	Energy and Environmental Research Corp. *E. Cichanowicz*
RP629-5	Support Services for Laboratory Fly Ash Simulation Development	9 months	52.3	Southern Research Institute *E. Cichanowicz*
RP724-2	Flue Gas Conditioning for Enhanced Precipitation of Difficult Ashes	26 months	1354.1	Southern Research Institute *R. Altman*
RP779-23	Wyodak Solvent Refined Coal Upgrading System	1 year	80.0	University of Wyoming *N. Stewart*
RP986-6	Gasification–Combined-Cycle Plant Configuration Studies	1 year	86.9	Westinghouse Electric Corp. *M. Gluckman*
RP989-3	Combustion Catalysts for Coal-Derived Liquids With High-Bound Nitrogen	10 months	205.4	Acurex Corp. *L. Angello*
RP991-9	Penetration Analysis of Fossil Fuel and Advanced Power Generation Systems	6 months	33.4	Westinghouse Electric Corp. *O. Gildersleeve*
RP1030-8	Cleaning Fine Coal With the Reichert Cone	6 months	39.2	Colorado School of Mines Research Institute *K. Clifford*
RP1030-90	Cleaning Fine Coal With the Reichert Cone	5 months	39.2	Mineral Deposits Limited *K. Clifford*
RP1079-2	Baseline Data on Utilization of Low-Grade Fuels in Gas Turbine Applications	1 year	148.8	Westinghouse Electric Corp. *R. Duncan*
RP1084-5	Application of AC/DC Systems to Damp Subsynchronous Resonance	6 months	38.6	Purdue Research Foundation *T. Yau*
RP1087-2	Assessment of Practical Potential for Heat Recovery and Load-Leveling on Refrigeration Loads	1 year	13.3	Applied Energy Systems *R. Mauro*
RP1179-5	Design and Evaluation of a System to Monitor Reducing Zones for the EPRI/B&W 6′ × 6′ Fluidized-Bed Combustion Facility Test Program	6 months	38.5	Radian Corp. *W. Howe*
RP1180-10	Compendium of Precipitator Plate Rapping and Re-entrainment Studies	3 months	15.6	Joy Manufacturing Co. *O. Tassicker*
RP1187-3	High-Reliability Gas Turbine Combined-Cycle Development	14 months	528.1	General Electric Co. *R. Duncan*
RP1197-3	Preliminary Evaluation of Copper Sulfate Process for Removal of Hydrogen Sulfide Over a Range of Geothermal Steam Conditions	15 months	28.9	EIC Corp. *E. Hughes*
RP1198-5	Complex Redox Couples for Bulk Energy Storage Applications	14 months	61.6	Giner, Inc. *W. Spindler*
RP1200-4	Phosphoric Acid Fuel Cell Catalyst Sintering Studies	7 months	70.3	Exxon Research and Engineering Co. *E. Gillis*
RP1200-5	Oxygen Reduction in Concentrated Phosphoric Acid by Carbon-Supported Platinum Alloy Catalysts	1 year	77.6	University of California at Berkeley *J. Appleby*
RP1200-6	Bonded-Phosphorus, Arsenic, and Sulfur Ligands to Prevent Platinum Fuel Cell Cathode Sintering	1 year	76.6	ECO Incorporated *A. Appleby*
RP1260-6	Characterization of Utility Wastes Using EPA and ASTM Leachate Methods	10 months	20.0	American Society for Testing and Materials *D. Golden*
RP1265-5	Failure Cause Analysis for Boiler Control Systems	9 months	47.9	Jaycor *J. Dimmer*
RP1266-15	Assessment of Control System Technology Used in Generating Plants	1 year	79.5	Analytical Sciences Corp. *J. Dimmer*

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
RP1275-3	Advanced Heat Recovery Systems/ Thermal Storage Systems for Industrial Applications	17 months	67.7	Charles A. Berg Associates *R. Mauro*
RP1276-1	Evaluation of Dual-Energy Use System Cogeneration Survey	6 months	94.6	TRW, Inc. *R. Mauro*
RP1319-2	Advanced-Cooling Full-Scale Engine Demonstration	1 year	1052.5	Westinghouse Electric Corp. *A. Cohn*
RP1319-4	Advanced-Cooling Full-Scale Engine Demonstration	4 months	109.8	Westinghouse Electric Corp. *A. Cohn*
RP1337-1	Protective Coatings or Claddings for Turbines in Pressurized Fluidized-Bed Combustion Systems	2 years	387.8	General Electric Co. *J. Stringer*
RP1346-1	Assessment of Particle-Beam Inertial Fusion	9 months	146.1	La Jolla Institute *F. Ford*
RP1347-1	Fusion-Fission Feasibility: Blanket Data Requirements	11 months	244.9	Westinghouse Electric Corp. *N. Amherd*
RP1348-3	Thermophotovoltaic Conversion Using Conventional High-Temperature Heat Sources	9 months	69.4	Black & Veatch Consulting Engineers *E. DeMeo*
RP1400-3	Coal-Cleaning Test Facility, Phase 1	17 months	326.3	Kaiser Engineers Inc. *K. Clifford*
RP1401-1	Reliability Assessment of Particulate Control Systems	26 months	459.2	Burns & Roe, Inc. *W. Piulle*
RP1408-1	Development of Low-Pressure Turbine Coatings Resistant to Steam-Borne Corrodents	2 years	801.9	Westinghouse Electric Corp. *K. Kinsman*
RP1412-3	Logistics Management of Shale Oil Test Material	9 months	105.7	Radian Corp. *L. Angello*
RP1414-1	Fusion-Fission Feasibility: Fuel Cycle Analysis	15 months	350.0	University of Wisconsin *N. Amherd*
RP1415-1	Thermophotovoltaic Conversion: Thermal and Optical Performance	9 months	198.3	Science Applications, Inc. *E. DeMeo*
RP1461-1	Development of a Reliability Prediction Methodology for a Gasification–Combined-Cycle Power Plant	11 months	187.2	ARINC Research Corp. *J. Weiss*
RP1466-1	Augmentation of Food Industry Computer Model (ALINET) to Provide Information on Energy Use	2 years	93.8	Systems Control, Inc. *R. Mauro*

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
Nuclear Power Division				
RP341-2	Investigation of Alternative Emergency Core-Cooling System	2 years	245.8	University of Buffalo Foundation, Inc. *R. Duffey*
RP399-2	Scale-Model Turbine Missile-Casing Tests	6 months	61.8	SRI International *G. Sliter*
RP399-3	Analysis of Steel Rings Subjected to Fragment Impact	4 months	7.5	Massachusetts Institute of Technology *G. Sliter*
RP399-4	STEALTH Calculations of Turbine Missile-Casing Impact	7 months	25.0	Science Applications, Inc. *G. Sliter*
RP895-12	Continuous Fission-Product Monitoring	11 months	95.3	Babcock & Wilcox Co. *F. Gelhaus*
RP1124-2	Turbine Chemical Monitoring	17 months	186.2	Westinghouse Electric Corp. *T. Passell*
RP1176-4	Technical Support Services for COMETHE Fuel Performance Code	2 months	10.0	S. M. Stoller Corp. *F. Gelhaus*
RP1227-3	Experimental Assistance for Nuclear Safety and Analysis	1 year	100.0	Science Applications, Inc. *R. Duffey*
RP1233-4	Value/Impact Analysis	5 months	42.0	Science Applications, Inc. *G. Lellouche*
RP1243-1	Comparison of Generic BWR Main Steam Isolation Valve Configurations	19 months	206.6	Atwood and Morrill Co., Inc. *R. Swanson*
RP1245-2	Developing Controlled and Programmed Flaws in Heavy Section Weldments	11 months	151.8	Westinghouse Electric Corp. *K. Stahlkopf*
RP1250-2	Zircaloy Corrosion and Crud Deposition Review	7 months	42.5	Atomic Energy of Canada Ltd. *H. Ocken*
RP1326-1	Development of an Irradiated Crack Arrest Toughness Data Base	27 months	1050.8	Westinghouse Electric Corp. *T. Marston*
RP1377-3	Analysis of Spray Distribution in Air and Steam Atmospheres	4 months	30.0	Jaycor *M. Merilo*
RP1378-1	Diversion Cross Flow Caused by Subchannel Blockages in Fuel Rod Bundles	1 year	61.4	Ecole Polytechnique (Canada) *M. Merilo*
RP1382-1	Factors Affecting Postdeparture from Nucleate Boiling Operations for LWRs	1 year	103.0	Combustion Engineering, Inc. *P. Bailey*
RP1382-2	Factors Affecting Postdeparture from Nucleate Boiling Operations for LWRs	1 year	105.0	Babcock & Wilcox Co. *P. Bailey*
RP1385-1	PWR Transient Tests at Arkansas Nuclear One, Unit 2	15 months	169.2	Combustion Engineering, Inc. *R. Whitesel*

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
RP1389-1	Measurements and Comparisons of Generic BWR Main Steam Isolation Valves	8 months	90.0	General Electric Co. *R. Swanson*
RP1392-1	Iodine Spiking in LWR Coolant	2 years	273.5	Babcock & Wilcox Co. *A. Miller*
RP1395-4	Digital Techniques for Improved Flaw Detectability	2 years	129.1	Purdue Research Foundation *G. Dau*
RP1398-1	Turbine Disk Failure Analysis	4 months	18.5	Southwest Research Institute *M. Kolar*
RP1399-1	Development of an Advanced Methodology for LWR Dosimetry Applications	1 year	180.0	Union Carbide Corp. *O. Ozer*
RP1440-1	In Situ Calibration of Reactor Safety System Resistance Temperature Detectors	13 months	88.0	Union Carbide Corp. *D. Cain*
RP1448-1	Quick-Response Evaluation of Critical In-service Inspection Issues	13 months	99.0	Battelle, Pacific Northwest Laboratories *G. Dau*
RP1448-4	Welded Pipe Stress Measurements	1 year	19.4	University of Denver *M. Povich*
RP1448-5	Technique to Improve Ultrasonic Testing Methods for Crack Location, Detection, Sizing in BWRs With Manual Transducer Positioning	8 months	29.2	Zeger-Abrams, Inc. *M. Lapides*

Electrical Systems Division

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
RP214-2	New Methods and Chemicals to Control Tree Regrowth, Phase 2	3 years	87.0	U.S. Department of Agriculture *R. Tackaberry*
RP1286-2	Optimization of the Design of Metallic Shield or Concentric Neutral Conductors of Extruded Dielectric Cables	29 months	543.6	Pirelli Cable Corp. *H. Songster*
RP1355-5	Automatic Load Forecasting	9 months	28.1	University of Nebraska *D. Koenig*
RP1357-3	Examination of Molecular Weight Distribution and Rheological Properties of a Limited Number of Field and Retained Cable Samples	15 months	10.0	University of Connecticut *B. Bernstein*
RP1420	Development and Testing of Multiple-Function Electronic Watthour Meter	44 months	745.2	McGraw-Edison Co. *W. Blair*
RP1421-1	Metal Oxide Surge Arresters for Gas-Insulated Substations	1 year	235.9	Gould Inc. *V. Tahiliani*
RP1423-2	Explosion-Resistant Bushing for Gas-Insulated Equipment	27 months	285.9	Gould Inc. *V. Tahiliani*
RP1424-1	Insulation—Cooling System for HVDC Converter Transformers	18 months	388.1	EHV Weidmann Industries, Inc. *E. Norton*
RP1426-1	Unified Active and Reactive Power Modulation Control of High-Voltage DC Systems	18 months	299.3	General Electric Co. *S. Nilsson*
RP1468-1	Component Outage Data Analysis Methods	20 months	307.4	Westinghouse Electric Corp. *M. Bhavaraju*
RP1473-1	Superconducting Generator Development	5 years	9320.7	Westinghouse Electric Corp. *J. Edmonds*

Energy Analysis and Environment Division

Number	Title	Duration	Funding ($000)	Contractor/ EPRI Project Manager
RP434-27	Electric Utility Rate Design Study	6 months	20.7	Ernst & Ernst *R. Malko*
RP862-15	Visibility Measurement Technique Intercomparison in the Eastern United States	18 months	241.9	Aerovironment, Inc. *G. Hilst*
RP1016-2	Methods for Combining Energy Models	6 months	54.5	Harvard University *R. Richels*
RP1104-3	Economic Value of Electricity Supply Reliability to Consumers	9 months	49.2	National Economic Research Associates, Inc. *M. Searl*
RP1220-3	Effects of Uncertainty on Energy Supply Elasticity: Principal-Agent Model	2 years	99.9	Purdue Research Foundation *A. Halter*
RP1224-4	Effects of Chlorine Stress on Establishment and Development of Communities of Attached Marine Organisms in Flowing-Water Systems	32 months	205.1	Battelle, Pacific Northwest Laboratories *R. Kawaratani*
RP1298-2	Analysis of Decision Methodology Relative to Adoption of New Technology	17 months	120.7	Economic Modelling Consultants *A. Halter*
RP1299-1	Technological Change in the Energy Supply Industry	22 months	198.1	General Electric Co. *J. Chamberlin*
RP1364-1	Analysis of Field Test Data on Residential Heating and Cooling	16 months	198.9	Battelle, Columbus Laboratories *E. Beardsworth*
RP1374-1	Environmental and Socioeconomic Consequences of a Shortage in Installed Generating Capacity	18 months	299.9	Mathematica, Inc. *R. Wyzga*
RP1431-1	Intermediate-Term Coal Supply	20 months	305.0	ICF Incorporated *T. Browne*
RP1487-1	Toxicant Extraction Procedure and Utility Industry Solid Waste	7 months	42.2	Acurex Corp. *R. Perhac*
RP1487-2	Toxicant Extraction Procedure and Utility Industry Solid Waste	7 months	30.9	Camp Dresser & McKee Inc. *R. Perhac*
RP1487-4	Toxicant Extraction Procedure and Utility Industry Solid Waste	7 months	33.5	Systems, Science & Software *R. Perhac*

New Technical Reports

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

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

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ELECTRICAL SYSTEMS

Bipolar HVDC Transmission System Study Between ±600 kV and ±1200 kV: Insulation Studies

EL-963 Interim Report (RP430-2)

An investigation was carried out by Institut de Recherche de l'Hydro-Québec (IREQ) on the behavior of the air insulating gaps of a bipolar dc line or a bipolar bus of a dc station, for system voltages of up to ±1200 kV. A typical arrangement of a monopolar rigid bus was used for these tests; the bus was supported at one end by an insulator column mounted on a metallic pedestal. Various terminations of the upper and lower end of the insulator column were tested, and for each set of terminations the breakdown voltage was obtained for the full range of ratios of the two components of the composite voltage. The most important conclusions of these tests were (1) the breakdown voltage of a gap stressed by a composite voltage may be even lower than that corresponding to a switching impulse of critical front, which, so far, has been considered the lowest breakdown voltage for any gap and (2) the ratio of the voltage components for which the minimum breakdown voltage occurs, as well as the value of this minimum, depends on the terminations of the two ends of the gap. *EPRI Project Manager: J. M. Silva*

Development of Nb_3Ge for Power Transmission Applications

EL-965 Final Report (RP7855-1)

This report from Los Alamos Scientific Laboratory describes a successful effort to develop a chemical vapor deposition process by which long lengths of superconducting Nb_3Ge–clad tape can be produced. The tape consisted of a copper substrate 0.65 cm wide × 25 μm thick, coated uniformly with a 4-μm-thick layer of Nb_3Ge. The results of a parallel effort to optimize Nb_3Ge for high critical currents at high temperatures are described. *EPRI Project Manager: Mario Rabinowitz*

Improvement of Civil Engineering Techniques for Buried Transmission Cables

EL-969 Final Report (RP7870-1)

This report from Bechtel National, Inc., summarizes underground cable installation techniques and equipment and recommends actions to reduce installation costs in the short term and develop improvements for the long term. A reference case installation along a specified alignment is compared in terms of cost and environmental impact with a conceptual case. The conceptual case—using water-jet pavement cutters, unitized shoring systems, and specialized trenching equipment—is faster and less expensive than the reference case, with the exception of a pneumatic backfill conveyor. The environmental impact of both cases is similar. *EPRI Project Manager: Thomas Rodenbaugh*

Cyclic Load Capabilities of Fossil-Steam Generating Units

EL-975 Final Report (TPS77-732)

Large fossil and nuclear steam-generating units, intended primarily for baseload operation, generally do not have large load-turndown and two-shift cycling capabilities. Consequent loss of operating flexibility is slowly creating potential problems for power system operation. The FPA Corp. assessed the minimum operating load and cycling capabilities of 1387 fossil-fueled units. Groups of units are classified according to common design, operating pressure, and fuel. Specific constraints are identified that will prevent operation at low minimum loads and cycling. Unit-regulating ranges, response rates, and response-rate constraints are also included. *EPRI Project Manager: Charles Frank*

Interconnected Power Systems Operation at Below Normal Frequency

EL-976 Final Report (TPS78-784)

This study was prompted by the interest of the North American Power System Interconnection Committee in addressing the problems of a sufficient generating capacity loss on any large interconnected power system. The principal concern of this study by consultant F. R. Schleif is to determine the range of tolerable frequency deviation for the affected interconnected system. Suggested operating strategies for maintaining a tolerable frequency within narrow limits are suggested. *EPRI Project Manager: Charles Frank*

ENERGY ANALYSIS AND ENVIRONMENT

Patterns of Energy Use by Electric Appliances

EA-682 Final Report (RP576)

A survey of 2000 households in 16 U.S. cities was conducted by Midwest Research Institute to provide information about the energy consumption of major electric appliances in the home. The monthly electric utility bills of the surveyed households were collected from August 1976 to July 1977, and a total of 900 major appliances were metered in 150 of the homes to determine electricity use for the same one-year period. The results of this study include (1) the extent of major electric appliance ownership and factors that affect ownership, (2) the total electricity used in the home and factors affecting electricity use, (3) the electricity used by major appliances and factors affecting this use, (4) the amount of natural gas used in residences, and (5) an extensive residential energy data base on a statistically reliable sample. *EPRI Project Manager: James Boyd*

Impacts of Future Transit Systems on Electric Utility Loads and Energy Consumption

EA-784 Phase I Report (RP1051-1)

The project is designed to analyze the long-range effects that future transportation systems may have on electric energy demand. This Phase I report by Howard R. Ross Associates describes the status of technological development of conventional and advanced transit modes in the United States, Western Europe, and Japan and formulates five hypotheses for future transportation developments to the year 2030. Special attention is given to an automated system consisting of electrically powered vehicles, using noncontact power collection devices retrofitted into existing highways, plus on-board energy storage. *EPRI Project Manager: Anthony Lawrence*

Coal in Transition: 1980–2000

EA-967 Final Report (RP875-1)

Headquartered at Stanford University, the Energy Modeling Forum operates through a series of working groups of energy model developers and users to make comparative tests of a variety of energy models. One of these groups, under the direction of David Sternlight, chief economist at the Atlantic Richfield Co., examined 10 models used to analyze the level and composition of coal production during the period 1980–2000. Results from that study show that all the models indicate a dramatic shift in the proportion of total U.S. coal production in the West under a variety of alternative assumptions about regional economics and environmental standards. *EPRI Project Manager: Stephen Peck*

Review of Large-Scale Energy Models

EA-968 Final Report (RP333-1)

Charles River Associates conducted a critical review of selected energy-economy models: energy-oriented macroeconomic growth models, interindustry models, energy sector models, and models of individual energy industries. A comparison was made of the effectiveness of each model in capturing pertinent structural features of the energy economy and each model's empirical quality and suitability for planning, technology assessment, and policy analysis. Also considered were factors affecting model choice, regionalization of economywide models, linked systems of separately developed models, documentation and independent performance testing, data development, quality control, and model maintenance. *EPRI Project Manager: Stephen Peck*

Integrated Analysis of Load Shapes and Energy Storage

EA-970 Final Report (RP1108-2)

An integrated framework was developed by Decision Focus, Inc., to analyze advanced batteries and heat- and cold-storage systems. Structural models were developed to describe electric demand growth, load shape, storage application, and electricity generation costs. Preliminary analysis of an energy storage device with a daily charge-discharge cycle led to several tentative conclusions: Optimal storage capability is 3–8 kWh of energy storage per kilowatt of discharge capacity; the potential value of daily storage is independent of summer or winter peaking; and the reduction in generation costs is roughly the same for year-round electricity storage as it is for heat storage used only during cold months on a winter-peaking system. *EPRI Project Manager: Stephen Peck*

Workshop on Atmospheric Pollution by Trace Nitrogen Compounds

EA-986-SY Workshop Summary Report (WS-78-77)

This document summarizes the findings of a workshop on atmospheric pollution by trace nitrogen compounds held in April 1978. The objectives of the workshop were (1) to review the current state of knowledge of atmospheric nitrogen compounds and identify significant environmental impacts associated with these compounds, (2) to appraise current knowledge of the formation, transport, and fate of nitrogen compounds in the atmosphere, and (3) to identify significant gaps in knowledge and the specific areas of research needed to clarify the present and future contribution of electric utility plants to nitrogen-related environmental impacts. Prepared by Battelle, Columbus Laboratories, this report reviews discussions on atmospheric nitrogen compound sources, transformations, sinks, and environmental effects. *EPRI Project Manager: Glenn Hilst*

Planning Guide for Source Assessment of Coal Conversion Facilities

EA-990 Final Report (TSA-78-165)

This planning guide, prepared by SRI International, presents the state of the art of source assessment technology applied to coal conversion facilities, discusses factors to be taken into account in planning a source assessment program, delineates requirements for sensitivity, precision, and accuracy of sampling and analysis protocols, and identifies deficiencies in methodology and research needs. The information is presented in outline form. A bibliography is included as a source of additional information. *EPRI Project Manager: Peter Jones*

Economic Geology of Uranium, Pine Creek Geosyncline, Northern Territory, Australia

EA-994-SR Special Report (CSA-78-4)

The sediments and metasediments of the Pine Creek geosyncline are host to the historic uranium deposits of the Rum Jungle district (∿3800 t), and South Alligator Valley (∿770 t), and beginning with their discovery in 1968, the large uranium deposits of the East Alligator River area (>345,000 t). This special report provides a guide to the literature on the uranium district of this region and assesses theories of ore genesis for each district. A broader treatment of the topic of the near-term availability of Australian uranium is included in *Foreign Uranium Supply*, EPRI EA-725. *EPRI Project Manager: Jeremy Platt*

FOSSIL FUEL AND ADVANCED SYSTEMS

Data Base for Flue Gas Cleaning Wastes

FP-671 Final Report, Vols. 1 and 2 (RP786-2)

This report from Radian Corp. documents the data base (as of mid-1977) for the disposal of flue gas desulfurization sludge and fly ash. Volume 1 reviews information characterizing the chemical and physical nature of these wastes and various admixtures. Conventional and commercial fixation technologies, laboratory and field studies, physical and engineering properties, and potential bacterial interactions of FGD sludge were investigated. Volume 2 documents laboratory research that evaluated the physical stability and leachability of fly ash and scrubber sludge. Fourteen U.S. fly ashes produced from bituminous, subbituminous, and lignite coals were characterized for chemical composition, alkalinity, and specific gravity. *EPRI Project Manager: Thomas Morasky*

Measurement of Particle Migration Velocities in Electrostatic Precipitators

FP-739 Final Report (RP363-1)

This work was directed toward obtaining a better understanding of the operation of electrostatic precipitators through the measurement of particle migration velocities. During the initial phase of the project, a laboratory-scale, two-stage precipitator was used by Washington State University to develop the instrumentation and to provide data on precipitator performance. In the second phase, a larger, improved system for measuring particle velocity was built and tested on electrostatic precipitators at the Centralia power plant. *EPRI Project Manager: Owen Tassicker*

Upgrading of Coal Liquids for Use as Power Generation Fuels

AF-873 Annual Report (RP361-2)

Residual coal liquids were hydroprocessed at Mobil Research and Development Corp. in a fixed-bed unit to upgrade them to high-quality power generation fuels. SRC products produced at short contact times were upgraded to the same extent as regular SRC when processed under similar conditions; a kinetic model linking the rates of conversion and heteroatom removal to the operating conditions was developed. In a 30-day aging study conducted on an H-Coal distillate product, an aging rate of 5–10°F per month indicated that acceptable cycles can be obtained. Tests in a small-scale turbine combustor at Westinghouse Electric Corp. indicated that H-Coal and SRC distillate liquids would be unacceptable in today's gas turbines; however, when hydroprocessed, these liquids gave results comparable to a No. 2 petroleum fuel oil. *EPRI Project Manager: William Rovesti*

Cocurrent Scrubber Evaluation: TVA's Colbert Lime/Limestone Wet-Scrubbing Pilot Plant

FP-941 Final Report (RP537-1)

The Tennessee Valley Authority is engaged in a pilot plant program to develop and/or evaluate wet-scrubbing processes for removing sulfur dioxide (SO_2) from boiler flue gas. Preliminary screening tests were performed at TVA's Colbert 1-MW pilot steam plant to develop operating data for use in designing and operating a 10-MW prototype cocurrent scrubber at TVA's Shawnee scrubber test facility. Results of the Colbert tests showed excellent SO_2 removal efficiencies (generally greater than 85%), low pressure drop, and high particulate removal efficiencies. *EPRI Project Manager: Thomas Morasky*

Evaluation of the Potential for Producing Liquid Fuels From Biomaterials

AF-974 Final Report (TPS77-716)

The major objective of this study by the University of Oklahoma was to determine the technological feasibility of methods for producing liquid fuels from biomass. A literature search was undertaken to evaluate the large majority of biomass conversion technologies. Immediate design and construction of a large-scale biomass-to-fuel liquids plant is not feasible at this time. Essential design information describing the nature of available biomass, seasonal variations, and changes of biomass during storage, and detailed process design and scale-up information are not available. The most promising processes involve gasification (followed by liquid fuels synthesis) and biochemical conversion. *EPRI Department Director; Dwain Spencer*

Antisolvent-Induced Agglomeration of Mineral Matter in Coal-Derived Liquids

AF-955 Final Report (RP774-1)

The influence of many variables associated with antisolvent-induced agglomeration of mineral matter in coal-derived liquids was observed at West Virginia University by an indirect X-ray photographic technique. The primary variables were antisolvent type; dose; combinations of antisolvent and a gas, temperature, antisolvent addition rate; and mixing conditions. A correlation relating the effectiveness of various antisolvents, as evidenced by an increase in the initial settling rate, with their carbon-hydrogen ratio and solubility parameter is proposed. Above a critical gas pressure, an increase in initial settling rate was observed for a fixed antisolvent dose. At a fixed gas pressure, an increase in initial settling rate resulted, with the antisolvent-to-oil ratio above a critical value. *EPRI Project Manager: Norman Stewart*

Cost Estimate of Fluidized-Bed Combustor Air Heater for Gas Turbines

FP-995 Final Report (TPS76-664)

Curtiss-Wright Corp. conducted a study of the performance, design concept, and capital cost of an unconventional coal-burning gas turbine system, including a pressurized fluidized bed (PFB) operating near stoichiometric fuel-air ratios. The system uses a clean air turbine heated by the PFB, as well as reduced-temperature combustion gases from the PFB. This power generation system is suitable for base, intermediate, and peak load service if the intervals between shutdown and startup do not exceed two to three days. Maximum single-unit capacity is 67 MW, and combined-cycle maximum thermal efficiency at a turbine inlet temperature of 1033 K (1400°F) is 33.2%, which is a heat rate of 10,295 Btu/kWh. Capital cost of the system per installed kilowatt is higher than for the DOE base design PFB system by about 20%, primarily due to the separate compressor-expander-generator equipment associated with the combustion air system and to the additional number of gas turbine modules. *EPRI Project Manager: Shelton Ehrlich*

FGD Sludge Disposal Manual

FP-977 Final Report (RP786-1)

This manual, developed by Michael Baker, Jr., Inc., is intended for utility operators of lime, limestone, alkaline fly ash, and double-alkali wet scrubbers. A decision path diagram illustrates available options and necessary steps for selecting a scrubber and disposal system, and these options are discussed in terms of existing regulations and possible requirements of the Resource Conservation and Recovery Act of 1976. The quantities of waste produced by three different processing methods are compared. Wet (ponding) and dry (landfill) disposal alternatives are described. *EPRI Project Manager: Thomas Morasky*

Requirements Assessment of Wind Power Plants in Electric Utility Systems

ER-978 Summary Report, Vol. 1 (RP740-1)

In this study General Electric Co. developed a rational approach to the consideration of wind power plants applied to electric utility systems and performed a requirements assessment and preliminary impact and penetration analyses by studying wind generation in three utility systems. Conventional utility loss-of-load probability and production simulation methods were used, together with a wind turbine generator (WTG) performance model. The value of wind power plants depends on wind regime, WTG design, utility system characteristics, and economic factors. Dedicated energy storage as an integral part of a wind plant does not offer an advantage because it does not optimize the total energy supply system of the utility. Of the generic machine designs in this study, the large (1500–2000 kW), horizontal-axis, constant-speed WTG in a central station configuration appeared to have the most potential for viability in electric utility systems. *EPRI Project Manager: Edgar DeMeo*

EPRI New Energy Resources Department Strategy Paper

ER-979 Final Report (TPS77-728)

The EPRI New Energy Resources (NER) Department serves as a focus for electric utility industry research efforts in the areas of fusion, solar, and geothermal. This report prepared by Booz, Allen and Hamilton, Inc., represents NER's initial efforts at strategy formulation. It details the rationale for national and utility industry involvement in NER technology and describes the procedures being used to formulate EPRI programs in each of the NER technologies. *EPRI Department Director: Piet Bos*

An Analysis of the Application of Fuel Cells in Dual Energy Use Systems

EM-981-SY Summary Report, Vol. 1
and EM-981 Final Report, Vol. 2 (RP1135-1)

Mathtech, Inc., assessed the technical and financial issues associated with utility-owned, grid-connected, dispersed fuel cells operating as dual energy use systems (DEUS) to provide economic intermediate or peaking duty for an electric utility system, and to satisfy thermal loads in the residential, commercial, industrial, and utility sectors. Both phosphoric acid and molten carbonate fuel cell types were considered. The results indicate that both types are economically attractive and technically viable for DEUS use in each of the application sectors. The most attractive applications for building systems include those in universities and hospitals, paper and pulp mills, and utility power plants (air for preheating). Economic benefits arise even if the DEUS power plants operate in the economic electric dispatch mode, which also results in significant petroleum savings because of the ~80% efficiency of DEUS fuel cells. *EPRI Program Manager: Arnold Fickett*

Nuclear Assay of Coal: Coal Composition by Prompt Neutron Activation Analysis

FP-989 Final Report, Vol. 1 (RP983-1)

Science Applications, Inc., conducted basic experiments to determine the composition of several types of coal by prompt neutron activation (PNA) analysis. Californium-252 was used as the neutron excitation source, and gamma photons emitted by elemental nuclei in the coal were measured with such detectors as sodium-iodide and germanium-lithium. Sulfur, hydrogen, carbon, aluminum, silicon, iron, calcium, sodium, nitrogen, and chlorine were determined by PNA methods, and the results were compared with those from traditional ASTM wet-chemistry analyses. *EPRI Project Manager: Owen Tassicker*

Nuclear Assay of Coal: Determination of Total Hydrogen Content of Coal by Nuclear Techniques

FP-989 Final Report, Vol. 3 (RP983-1)

This report reviews possible nuclear techniques for determining the total hydrogen content of coal. The study by Science Applications, Inc., shows that hydrogen is most accurately determined by measuring the leakage of epithermal neutrons from a slab sample 30 cm thick. Using this method, hydrogen density was measured with an average absolute error of 6.2×10^{-4} g/cm³. *EPRI Project Manager: Owen Tassicker*

Nuclear Assay of Coal: Moisture Determination in Coal

FP-989 Final Report, Vol. 4 (RP983-1)

This report from Science Applications, Inc., and Kennedy Van Saun Corp. consists of a survey of three moisture determination techniques, capacitance, microwave attenuation, and nuclear magnetic resonance (NMR), and the extent to which they have been applied to coal. Accuracies of ±1% absolute can be achieved with all three techniques. The two electromagnetic methods must be calibrated for physical parameters and coal types, while NMR is currently limited to small sample sizes and a "nonrugged" design. *EPRI Project Manager: Owen Tassicker*

Nuclear Assay of Coal: Mass Flow Devices for Coal Handling

FP-989 Final Report, Vol. 6 (RP983-1)

The mass flow rate of coal on a conveyor belt is generally determined as a product of the instantaneous mass of coal within a section of the belt and the belt velocity. Conventional transducers incorporating mechanical or electromagnetic weights or a gamma-ray attenuation gage can be used to measure mass flow. This report from Science Applications, Inc., and Kennedy Van Saun Corp. reviews the state of the art in mass flow measurement devices for coal handling. In particular, special designs are considered for a mass flow measuring device in a continuous on-line nuclear analysis of coal (CONAC) system. *EPRI Project Manager: Owen Tassicker*

Nuclear Assay of Coal: Coal Rheology and Its Impact on Nuclear Assay

FP-989 Final Report, Vol. 7 (RP983-1)

A number of possible techniques for introducing coal to a continuous on-line nuclear analysis of coal (CONAC) system were evaluated by Science Applications, Inc., and Kennedy Van Saun Corp. A modified flat-belt feeder system was recommended. The success of such a coal presentation technique would rely on proper entry to the feed hopper, shape of the withdrawal opening from the feed hopper, and a slow belt speed to minimize demixing. *EPRI Project Manager: Owen Tassicker*

Coal Gasification System Analysis

AF-992 Final Report (RP986-2)

This report presents the Phase I results of a study by United Technologies Corp. to define alternative gas turbine power plant cycles that could be effectively integrated with entrained-flow coal gasification plants. Cycles without steam bottoming and with thermal efficiencies approximately equal to those of combined-cycle power plants of comparable technology were devised. A major technological hurdle must be overcome before the selected cycle can become a practical reality. A fuel gas heat exchanger must be developed for operation in a corrosive fuel gas environment at an inlet temperature of 760–980°C (1400–1800°F). *EPRI Program Manager: Michael Gluckman*

System Definition Study: Solar Heating and Cooling Commercial Project

ER-993 Interim Report (RP844-1)

In a first-phase effort Arthur D. Little, Inc., identified potential commercial applications of solar and load management systems and selected several projects for continuation into a detailed design phase and ultimately into construction. Candidate projects were proposed by electric utilities and were evaluated with criteria based in part on a survey of the potential commercial solar market. The seven projects ultimately selected for continuation into a second phase and detailed design included a delicatessen, schools, and office buildings. *EPRI Project Manager: James Beck*

Battery Energy Storage Test (BEST) Facility

EM-1005 Interim Report (RP255-2)

The BEST Facility will be a national center for testing and evaluating electrochemical energy storage systems, including associated electrical conversion equipment developed for use on electric power grids. The BEST program consists of four phases: design, construction, testing and acceptance, and operation. This report from Public Service Electric and Gas Co. covers the activities of the first three phases from March 1, 1976, to July 1, 1978. Included in the report are a background review, a chronology of key events, a description of activities for the three phases (including those associated with the implementation of the second test bay), and a discussion of major interactions between the BEST program and the advanced battery development programs. *EPRI Project Managers: William Spindler and James Beck*

NUCLEAR POWER

A Risk Methodology Presentation
NP-79-1-LD Informal Report (RP1233-1)

Science Applications, Inc., presented a one-day tutorial on risk methodology applied to nuclear power systems. Basic probabilistic and risk concepts and examples of historical data were reviewed and event-tree and fault-tree analysis methodologies and associate EPRI computer codes were described. Results of applying these methods to the potential problem areas of seismic response and anticipated transients without scram in LWR safety were presented. This report is available free of charge from EPRI. *EPRI Program Manager: Gerald Lellouche; Report Coordinator: Patrick Bailey*

Core Design and Operating Data for Cycle 1 of Hatch 1
NP-562 Final Report (RP130-3)

This report from General Electric Co. contains the design and operating data needed to define the fuel and reactor operation characteristics for Cycle 1 of the Hatch Nuclear Power Plant, Unit 1. The purpose is to provide reference-quality data for use in the qualification of reactor core analysis methods and to provide the basis for assessment of irradiation environment up to and including the end of Cycle 1 gamma scan. The design data include a fuel assembly description, core component arrangements, control rod descriptions, core loading patterns, and hydraulic characteristics of assemblies and inlet orifices. Operating data are compiled for selected steady-state operating points during Cycle 1, including core average exposure, thermal power, pressure, flux, inlet subcooling, control configuration and axial in-core detector readings. *EPRI Project Manager: Robert Whitesel*

Application of Nonlinear Signal Processing to Pipe and Nozzle Inspection
NP-964 Interim Report (RP1125-1)

Adaptronics, Inc., conducted four studies during 1977–1978: (1) breadboard design and fabrication of a microcomputer-based instrument for nondestructive evaluation, (2) detection and sizing of cracks in stainless steel, (3) detection and sizing of cracks in feedwater nozzles, and (4) detection, classification, and sizing of defects in steam generator tubing. *EPRI Program Manager: Gary Dau*

Interphase Momentum Transfer in the Flow of Bubbles Through Nozzles
NP-980 Topical Report (RP443-2)

To understand and formulate the interaction forces between two phases, a laboratory experiment involving flow of bubbles through nozzles was undertaken by Dartmouth College. For fast data acquisition, a computer-based optical system was designed to work on the principle of the interruption of a light beam by a bubble passing between a collimated light source and a row of phototransistors. The bubble position along the nozzle (horizontal as well as vertical) is determined by its crossing through the light path to several rows of phototransistors attached to the nozzle. A mathematical model to predict bubble motion was developed to include the drag force, the apparent mass force, the buoyancy force, the bubble expansion force, and the history forces. Results show that the bubble trajectory can be predicted within 10% accuracy by an equation of motion that includes a suitable drag force (dependent on relative velocity) and an apparent mass force (proportional to relative acceleration). *EPRI Project Manager: K. H. Sun*

The Effects of Anisotropy and Irradiation on the Deformation Behavior of Zircaloy 2
NP-982 Final Report (RP456-2)

An experimental program was conducted by MIT to investigate the effects of texture anisotropy and irradiation on the mechanical behavior, both short-time and time-dependent, of Zircaloy 2. Short-time yield behavior was found to be a strong function of the crystallographic texture at all temperatures investigated. In general, the rate of texture rotation was found to be a unique function of the initial texture for plastic strains less than 0.08. Tensile creep strength was observed to be proportional to the resolved fraction of basal poles in the test direction. In the irradiation creep tests conducted, both irradiation hardening and enhanced irradiation creep behavior were observed. *EPRI Project Manager: Terry Oldberg*

Survey on Vertical Two-Phase Countercurrent Flooding
NP-984 Topical Report (RP1160-1)

The University of California at Berkeley examined an important problem in the safety analysis of an LWR, that is, the flooding phenomenon, or countercurrent flow limit, in the reflood process of the reactor core during a hypothetical LOCA. Published analytic models for predicting this condition, based on the analysis of hanging films and on the theory of small disturbance in falling films, are reviewed in this report. Experimental results and empirical correlations are summarized, and the parametric dependence of the countercurrent flow limit is discussed. Also included in the survey are various extended problems in flooding, including those with vapor condensation, liquid entrainment, flow inclination, complex system geometries, and multiple channels. *EPRI Project Manager: K. H. Sun*

Sensitivity of Nuclear Fuel Cycle Cost to Uncertainties in Nuclear Data
NP-985 Interim Report (RP975-4)

A sensitivity analysis system has been developed by Rensselaer Polytechnic Institute to evaluate the economic implications of uncertainties in nuclear data and related computation methods for LWRs. Two steps have been identified for this analysis. Path B determines the sensitivity of the fuel cycle cost to uncertainties in few-group, cell-averaged, microscopic cross sections. Path A relates these factors to uncertainties in the basic nuclear data and computational methods. Path B sensitivity investigations, using a few-group batch depletion code FASTCELL, a core analysis code (based on the Haling Strategy) FASTCORE, and a reactor cost code COSTR for some 90 nuclear parameters, revealed high-cost implications for thermal and resonance range cross sections in fissile and fertile materials. *EPRI Project Manager: Odelli Ozer*

Power Plant Early Alert Reporting System
NP-988 Final Report (TPS77-750)

A study was performed by S. M. Stoller Corp. to determine the scope, methodology, and cost of an early alert reporting system (EARS). The purpose of EARS will be to quickly and systematically inform operating power plants of problems that have affected other plants and that might also affect them. The principal conclusion of the study is that EARS should be made part of the outage cause reporting system described in EPRI NP-836. *EPRI Project Manager: William Lavallee*

Estimation of the Defect Detection Probability for Ultrasonic Tests on Thick Section Steel Weldments
NP-991 Technical Report (RP700-1)

Failure Analysis Associates conducted an inspection uncertainty analysis of published Pressure Vessel Research Committee Specimen 201 data. One purpose of this analysis was to estimate the probability of recording an indication as a function of imperfection height for ASME Code Section XI ultrasonic inspections of nuclear reactor vessel plate seams. The second purpose was to demonstrate the advantages of inspection uncertainty analysis over conventional detection/nondetection counting analysis. The probability of recording a significant defect with an ASME Code Section XI ultrasonic inspection was found to be high if such a defect should exist in the plate seams of a nuclear reactor vessel. Inspection uncertainty analysis gives more accurate estimates over a much greater flaw size range than is possible with conventional analysis. *EPRI Program Manager: Floyd Gelhaus*

^{238}U Resonance Self-Indication Capture Measurements and Analysis
NP-996 Interim Report (RP511-1)

Neutron self-indication measurements simulating ^{238}U capture in reactors have been carried out at Rensselaer Polytechnic Institute over the energy range from 3 eV to 3 keV, using shielding samples at 77 K, 293 K, and 873 K. The data have been reduced to capture yields provided on magnetic tape as benchmark data for comparison with nuclear design calculations. In the energy range below 100 eV, improved multilevel parameters of the s-wave resonances were obtained, leading to a lowering of the discrepancy between the calculated and measured resonance integral in ^{238}U thermal lattices. Multilevel stochastic analysis was applied to calculation of neutron capture in the valleys between resonances. It is shown that the cross section cannot be calculated accurately in the valleys without additional experimental information. *EPRI Project Manager: Odelli Ozer*

Fissions Determination in ^{239}Pu Sample
NP-997 Final Report (RP957-2)

A 40-mg sample of ^{239}Pu was irradiated for 24 hours at IRT Corp.'s ^{252}Cf facility as part of its program to measure fission product decay heat. The number of fissions created in this irradiation was measured at Oak Ridge National Laboratory by studying the gross gamma-ray spectra measured with high resolution for cooling times between 13 and 32 days. The number of fissions was determined to be $(1.326 \pm 0.019) \times 10^{11}$, using yields measured for the 228-keV (^{132}Te), 497-keV (^{103}Ru), and 1597-keV (^{140}La) gamma rays and calibration factors based on absolute fission counting. *EPRI Project Manager: Walter Eich*

Evaluation of Mechanized Pipe Welding

NP-1003 Final Report (TPS77-724)

The use of machine welding equipment and procedures for power plant pipe welding can consistently produce high-quality weldments. A principal concern is related to the reliability of the requisite sophisticated equipment in hostile environments. This report by Battelle, Columbus Laboratories reviews the current state of machine welding. *EPRI Project Manager: Richard Smith*

LWR Fuel Performance Program: Progress in 1978

NP-1024-SR Special Report

The goal of this program is to develop a comprehensive fuel performance data base with verified predictive models and codes to improve fuel rod reliability and hence increase plant availability. There are 18 active projects that range in scope from laboratory tests of Zircaloy cladding tube behavior to large-scale testing of prototypic fuel assemblies. During 1978 several projects or project phases were completed, yielding valuable information in the areas of Zircaloy properties under postulated LOCA conditions; modeling of Zircaloy inelastic deformation and fracture; improvement and utilization of LWR fuel rod modeling codes, including a cost of fuel failure model; the understanding and reduction of pellet-cladding interaction defects; and power reactor fuel performance limits, particularly fuel rod bow and fission gas release. *EPRI Program Manager: Adrian Roberts*

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

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