Global Response to CFC Refrigerants

Also in this issue:

- *Measuring Transmission Flows*
- *Infrared Paint Curing*
- *International Fuel Cell Development*

ELECTRIC POWER RESEARCH INSTITUTE

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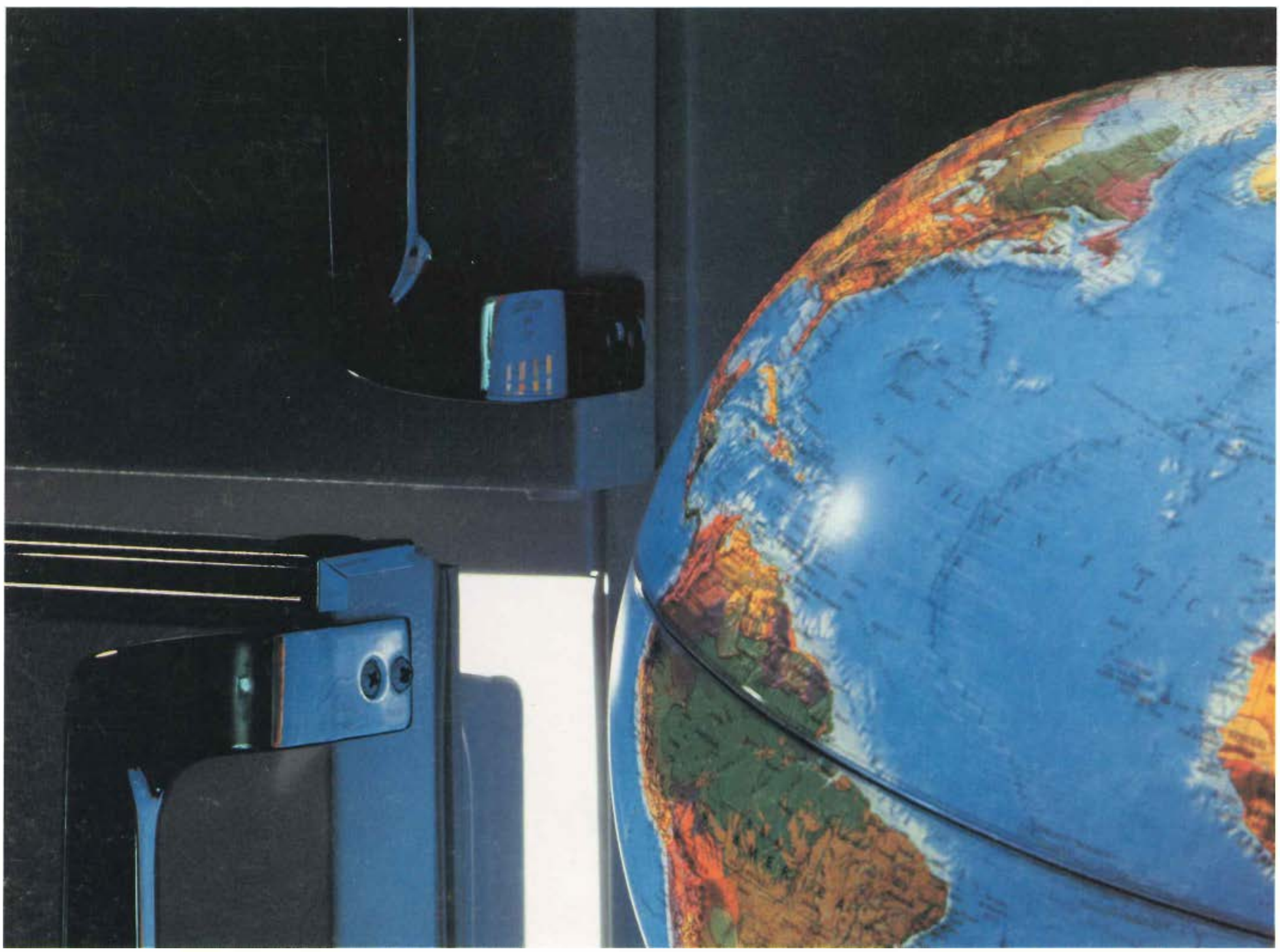

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Cover: The world is looking closely at the effects of chlorofluorocarbon refrigerants on the depletion of ozone in the upper atmosphere. While major industrialized nations have committed to substantial cutbacks in CFCs, many developing countries see these chemicals as crucial to their economic growth.

EDITORIAL

CFCs and the Energy-Environment Puzzle

Society is being bombarded with increasingly difficult energy and environmental issues. While the demand for energy continues to grow, no clear consensus has emerged on how—or even whether—that energy should be supplied. There are legitimate concerns with every energy supply option currently available: public concerns over nuclear safety, national concerns over petroleum imports, concerns over the effects of coal use on global climate and acid rain, and concerns over the long-term price and availability of natural gas. These concerns have created an energy-environment dilemma that will have major impacts on our future energy supplies and uses.

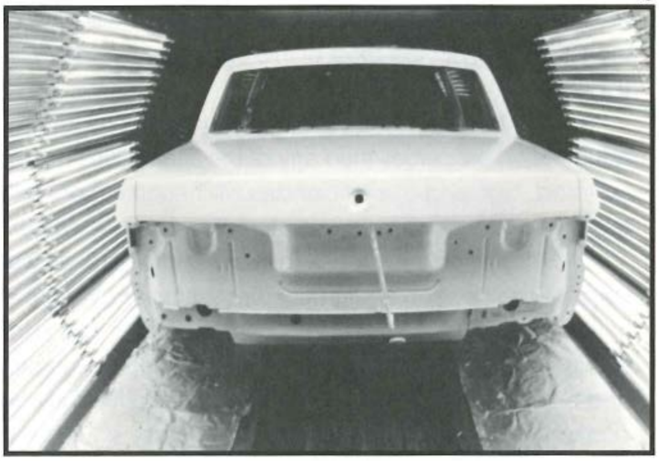
This dilemma is further complicated by the need to curtail the use of chlorofluorocarbons (CFCs) and other chemicals that attack stratospheric ozone. While scientific questions remain about the impacts of greenhouse gases and acid rain, there is no question regarding the science or the seriousness of the CFC-ozone problem and the need to act quickly. The cutback of CFCs under the 1987 Montreal Protocol will obviously have serious impacts for CFC-producing chemical companies and manufacturers of cooling equipment. But the electric utility industry cannot afford to see this just as somebody else's problem. Its stake is the greatest by far: over a quarter of the electric utility industry's revenues come from the sale of electricity that powers refrigeration and air-conditioning equipment across the residential, commercial, and industrial sectors, and most of this equipment uses CFCs or their cousins, hydrochlorofluorocarbons (HCFCs).

As is often the case, the environmental fix will cost us in efficiency: CFCs have significantly better refrigeration properties than any of the alternatives being considered to replace them. Thus, as CFCs are curtailed, high end-use efficiencies will become more difficult and costly to achieve. This will in turn tend to increase the need for energy supply—a classic catch-22 situation in the context of the larger puzzle.

The best response to the CFC problem, as well as to other complex energy–environment challenges, is to develop equipment that uses energy more efficiently and productively—equipment that will minimize requirements for new energy supplies and also their associated environmental impacts. This brings new urgency to the need for technological innovation in the next generation of end-use products and buildings. EPRI's growing portfolio of products is designed to address the concerns of efficiency and productivity across the broad front of end-use equipment. But avoiding disruption during the CFC transition will require the active support of all parties with a stake in refrigeration and cooling, utilities included.

Arnold P. Fickett

Arnold P. Fickett, Vice President
Customer Systems Division



DEPARTMENTS

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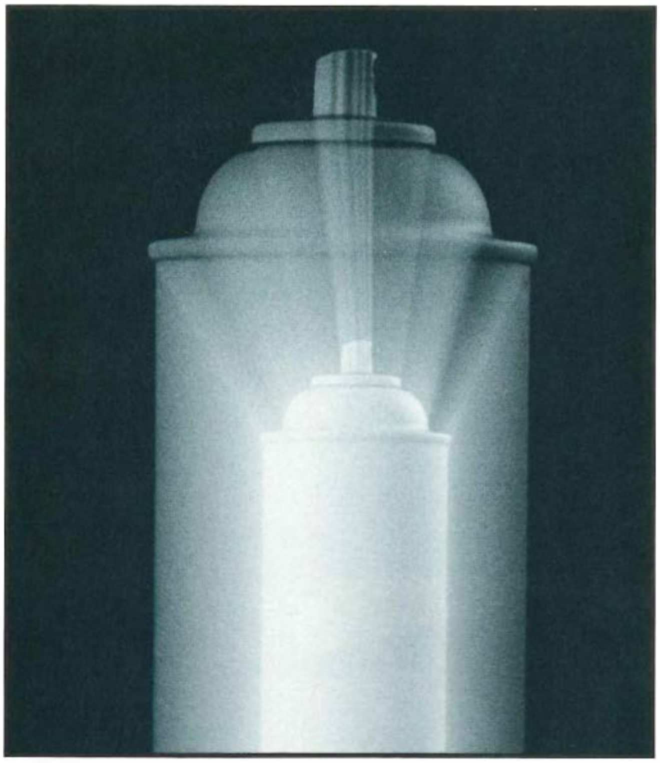
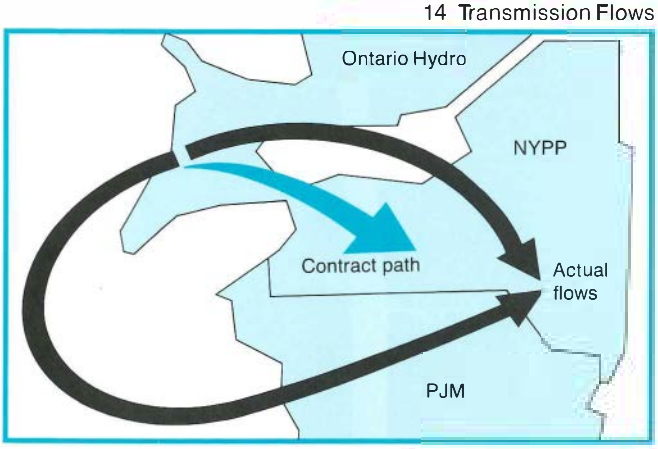


4 CFCs

14 Transmission Flows



The Challenge of Doing

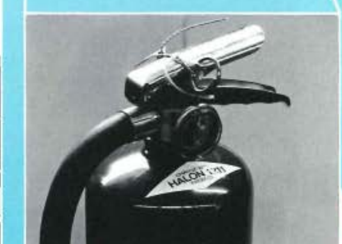
Mandatory cutbacks on the production and use of chlorofluorocarbons began this year under the Montreal Protocol, intended to slow the destruction of ozone in the stratosphere. The phaseout of these ubiquitous and highly efficient refrigerants will mean changes for a wide variety of end-use products and could have long-term effects on utilities as well.

CFCs

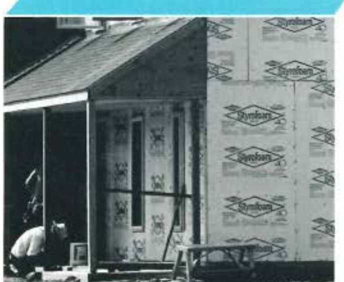
Home
refrigerator-freezer

Cold-drink
vending machine

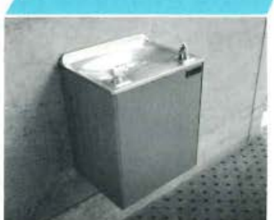
Mobile
refrigeration



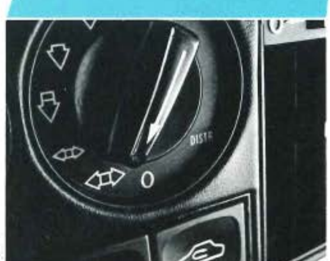
Halon
fire extinguishers



Rigid
foam insulation



Refrigerated
water fountain



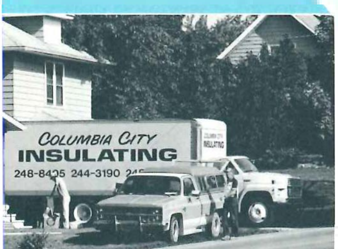
Auto
air conditioning

Aerosol
propellants

Industrial
freezer

Without

Grocery refrigerator



Flexible-foam-blowing agent

Solvents for electronic components

Effects of a first-of-a-kind international agreement to protect the ozone layer in the stratosphere are beginning to be felt at the level of nearly every home, automobile, and business. Although many people do not yet realize it, the refrigerants in auto air conditioners and home and supermarket refrigerators, as well as related chemicals widely used as blowing agents for foam insulation, as solvents, and as fire-extinguishing agents, are suddenly becoming scarcer and costlier, with serious long-term implications for energy use and domestic economies worldwide.

On July 1, Environmental Protection Agency (EPA) regulations to implement the 1987 Montreal Protocol in this country took effect, imposing cutbacks on U.S. production of five key chlorofluorocarbon (CFC) compounds containing chlorine. Similar restrictions begin in 1992 for halon gases containing bromine.

Scientists have confirmed in recent years that when released to the atmosphere, CFCs and halons, which are inert, eventually reach the stratosphere. Broken down by ultraviolet radiation, they give up free chlorine or bromine, which in turn disrupts normal stratospheric chemistry and causes a net diminution of the ozone that helps shield the earth from the sun's harmful ultraviolet radiation.

To slow the rise of stratospheric chlorine and bromine and thus stem the projected loss of ozone in the years ahead, over 35 countries agreed two years ago to cut the production and use of CFCs and halons in stages. The goal set then was an overall 50% reduction from 1986 levels by mid-1998.

About 2 billion pounds of CFCs were produced in non-centrally planned economies in 1986, including 700 million pounds in the United States alone. With the current annual world CFC market estimated at $1.8 billion and the U.S. market at over $600 million, prices for common refrigerants have already begun to rise. Surplus supplies have all but disappeared.

The implications of halving within the next nine years the widespread use of a unique class of chemicals deeply woven into the fabric of the modern world are serious indeed. Yet there are clear signs it will not be enough.

In Helsinki last May at a planned review of the Montreal Protocol in light of the latest scientific information on stratospheric ozone, 81 nations declared support for eliminating the manufacture and use of CFCs altogether by the end of the century, if acceptable replacements are available. All of the parties to the Montreal Protocol joined in the Helsinki declaration; independently, the United States and member countries of the European Community had earlier endorsed a total phaseout.

The writing on the wall should be clear enough by now: CFC compounds, a result of American industrial research that led to modern refrigeration, air conditioning, and a host of other products over the last 60 years, are on the way out, environmentally done in by the very essence of their commercial appeal.

Chemical companies that make CFCs are now in a headlong race the world over to find and develop acceptable substitutes or alternatives that can be mass-produced at an affordable cost. Myriad industries, meanwhile, whose products depend on CFCs as a working fluid or in insulation, are facing higher prices and tighter supplies of the chemicals in the near term.

Over the somewhat longer term, manufacturers face the prospects of redesigning equipment and retooling plants to manufacture compressors, auto air conditioners, commercial chillers, and all kinds of refrigeration systems (including domestic refrigerators and freezers) that will be forced to use less-efficient and otherwise less-than-ideal CFC substitutes.

The economic consequences for chemical companies and equipment manufacturers are significant. The annual market for refrigerants used in comfort-conditioning systems in buildings and in refrigeration systems is estimated at about $300 million. Annual shipments of refrigerant-using equipment in those sectors total an estimated $12 billion. Yet among all the industries that stand to be affected by the cutback or likely eventual phaseout of CFCs, electric utilities by far have the most at stake. Revenues from the sale of electricity last year for powering all vapor-compression devices (including some that do not use CFCs) were estimated at over $53 billion—28% of the total U.S. utility industry revenues in 1988.

"The potential impact on electric power demand and energy consumption is very large," says Arnold Fickett, vice president for EPRI's Customer Systems Division. "Utilities have a strong interest in seeing that the CFC alternatives that evolve will be safe and energy-efficient and will not exacerbate loads." EPRI is sponsoring studies of the implications of CFC cutbacks and possible substitutes.

The problem with chlorofluorocarbons

CFCs were invented to solve the toxicity problem of coolants that were perceived to be holding back the potential of the nascent home refrigerator market in the 1920s (see box, p. 10). The new family of chemicals soon came to be appreciated as virtually ideal refrigerants—they could be simply and cheaply made, they had the desired combination of safety and thermodynamic properties, and they were chemically stable and inert. It was not until some 40 years after their introduction that one of the key and originally most desirable features of CFCs was determined to have potentially disastrous consequences on the global environment.

"From an applications standpoint, CFCs really are the best possible refrigerants," says Powell Joyner, a project manager in EPRI's Customer Systems Division. "They were methodically identified and developed as a class of compounds with unique properties. The varied and sometimes conflicting criteria for a refrigerant, now further complicated by a material's ozone-depletion potential, mean that whatever is used or developed as a replacement is likely not going to be quite as good."

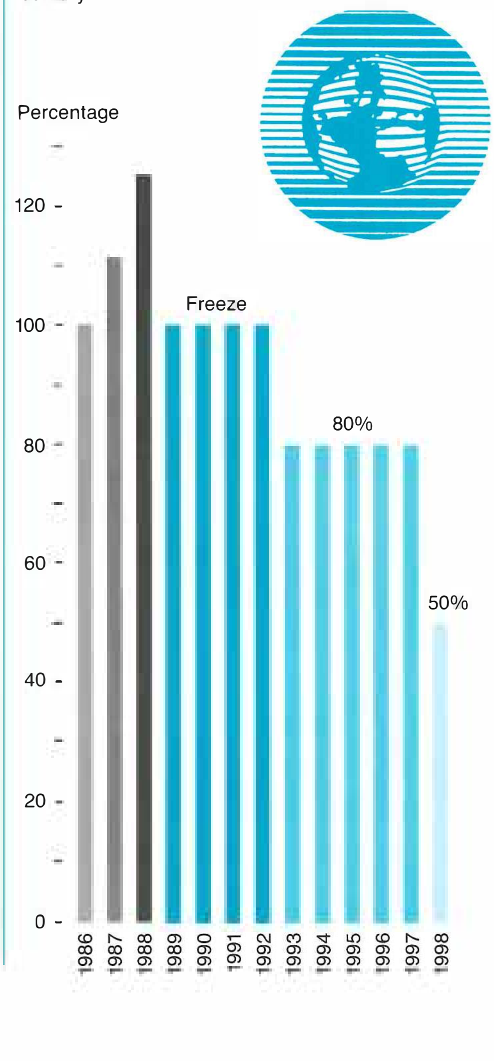
Since CFCs are chemically stable and do not react with other substances over time, they remain effective as coolants or solvents essentially indefinitely and can be used over and over. CFC-12, for example, works for decades in a hermetically sealed cooling circuit, such as in refrigerators. In contrast, auto air conditioners, which use CFC-12 in an open, mechanical-drive system prone to leakage at dried-out gaskets, are a major source of atmospheric emissions of CFCs. (CFC-12 and its close chemical relative CFC-11, which is used both as a refrigerant and as a blowing agent for foam and rigid insulation in appliances and buildings, are the principal CFCs for which cutbacks will affect national energy use.)

But the stability of CFCs in use also means that if the compounds do leak or are discharged when equipment is serviced, they do not react or break down in the lower atmosphere. Instead, over decades they rise into the stratosphere, where they are decomposed by ultraviolet radiation and release ozone-diminishing free chlorine. The long atmospheric lifetime of CFCs, 40 to 150 years, is related to their complete substitution of chlorine or fluorine atoms for all hydrogen atoms in a methane- or ethane-derivative molecule.

The proportions of hydrogen, chlorine, and fluorine in various refrigerant compounds play a critical role in the inherent trade-offs between other desirable and undesirable properties. Pure hydrocarbon—methane, for example,

Timetable for CFC Reductions

In the 1987 Montreal Protocol on Substances That Deplete the Ozone Layer, more than 35 countries, including the United States, agreed to reduce the production and use of CFC-11, -12, -113, -114, and -115 begining this year. Similar restrictions for halon gases 1211, 1301, and 2402 begin in 1992 under the agreement. For 1989 U.S. production of the targeted CFCs, or chlorofluorocarbons, is to be frozen at 1986 levels; then production will be cut further to achieve an overall 50% reduction from the 1986 levels by 1998. Since the adoption of the protocol, the United States and some 80 other nations have called for a total phaseout of CFCs by the end of the century.



with one carbon atom and four hydrogen atoms—is flammable. Pure chlorocarbon—carbon tetrachloride—is toxic. Chlorine and fluorine provide chemical stability.

Hydrogen may well be the key to substitutes or alternatives to CFCs. If at least one hydrogen atom is substituted for a chlorine or fluorine atom in a CFC molecule, desirable properties as a refrigerant or a solvent may be retained. But the compound is now less stable, and most or all of it will react or break down in the lower atmosphere before reaching stratospheric ozone. The difference can also mean the reintroduction of undesirable properties, such as material incompatibility or flammability (if too many hydrogen atoms are present).

Five such hydrochlorofluorocarbons (HCFCs) have been developed and are widely used. One, HCFC-22, is the refrigerant in almost all unitary (residential, window, and commercial rooftop) air-conditioning systems and heat pumps. Compared with CFC-11 or CFC-12, the HCFCs have only a fraction of the effect on stratospheric ozone. On a weight basis, HCFC-22's ozone-depletion potential is 5% of CFC-11's. Another HCFC, considered the best hope as a substitute for CFC-11, is HCFC-123; its potential effect on ozone is 2% of CFC-11's.

But some of the HCFCs eyed as substitutes for CFC-11 attack the varnish on motor windings and some are also flammable, their reduced ozone-depletion potential notwithstanding. Even if these drawbacks are overcome, the insulating values of candidate replacements for CFC-11 as the blowing agent in foam insulation are not likely to be as good. The implication, in the case of refrigerators, for example, is that either the outer dimensions will have to grow or the inner diameters will have to shrink in redesigned, future models in order to accommodate thicker, less effective insulation. Many modern home refrigerators are already squeezed into tight kitchen cubbyholes.

The HCFCs are not subject to the current EPA regulations implementing the Montreal Protocol. Indeed, until fairly recently CFC producers and user industries were touting HCFCs—mainly, in the case of refrigerants, numbers 22 and 123—as part if not most of the solution to the CFC problem. But the EPA has pointedly not ruled out limiting HCFCs sometime in the future.

Says EPRI's Joyner: "If the use of CFC-11 and CFC-12 and others is to be reduced to zero over the next decade to slow the rise in stratospheric chlorine, it is unrealistic to expect that, internationally or domestically, the use of HCFCs would be allowed to increase significantly. But if HCFC-22 were to be cut back, it could be a disaster for the heating, ventilating, and air-conditioning [HVAC] industry, because there is currently no acceptable substitute for 22."

The most desirable alternative compounds to CFCs contain no chlorine—only carbon, hydrogen, and fluorine. Such hydrofluorocarbons (HFCs) have no potential to deplete stratospheric ozone. Three HFC compounds have been developed in limited quantities so far. In important respects, however, they fall short of the CFCs it is hoped they could replace.

HFC-134a, for example, is being developed as an alternative to CFC-12 in auto air conditioners. Du Pont is building a new plant to make the compound, but commercial production is not expected to begin until the early 1990s, assuming that toxicity issues and lubrication problems are resolved. General Motors reportedly plans to use HFC-134a as a substitute coolant in some car models in the early to mid-1990s, but that will require the development of a new lubricant to mix with the refrigerant. And because 134a will be less thermodynamically efficient, evaporators and condensers will have to be larger and the compressor will need to be redesigned. Almost certainly, the upshot will be more weight, less passenger space, and lower fuel economy—at possibly higher cost.

Mixtures of refrigerants are also being considered. Du Pont recently announced a three-part blend of HCFC-22, HFC-152a, and HCFC-124 that has performance characteristics very close to those of CFC-12 and a very low ozone-depletion potential. However, HCFC-124 is not currently in commercial production, and there are uncertainties about its toxicity and about the flammability of HFC-152a in the ternary mixture.

Adding to the uncertainty over potential CFC alternatives is the greenhouse connection. Molecule for molecule, CFCs are 10,000 times more efficient in absorbing infrared radiation than is carbon dioxide, indicting them as contributors to potential greenhouse warming as well as to ozone depletion. They are believed to account for about one-fifth of the perceived warming that has been attributed so far to atmospheric pollution. Now, there are reports that HCFCs and even HFCs may also have significant potential to contribute to greenhouse warming.

Moreover, although toxicity testing of some CFC alternatives has been ongoing, testing of many substitutes has only just begun and is expected to take several years. Major CFC producers have organized joint toxicity testing in some cases to speed the assessment of alternatives.

Meanwhile, this August the United Nations Environment Program (UNEP), which is supervising implementation of the Montreal Protocol internationally, was to host a major scientific review of the ozone situation. In addition to considering the Helsinki declaration for a ban on CFCs by century's end, the UNEP review was expected to hear calls for controls on carbon tetrachloride, the manufacturing precursor of CFCs, and on methyl chloroform. Both are extensively used as solvents and in other applications and are considered to contribute to stratospheric chlorine as much as or more than CFCs do. In fact, the EPA has proposed adding these chemicals to the list covered under the Montreal Protocol.

One substance that could represent a fallback option as a refrigerant in the event of a broad ban on HCFCs as well as CFCs is propane. Although it is flammable, propane is thermodynamically suitable for most electricity-powered cooling applications that now use CFC-12 or HCFC-22. It is of low toxicity and would not require extensive testing in that respect. There is some industrial experience with propane as a refrigerant, but its use in residential cooling applications would require changes in both equipment and regulatory codes. The amount of propane consumed for heating and cooking annually in the United States is some 50 times more than the yearly production of CFCs.

Feedback far and wide

Given the wide range of common products and equipment that now use chlorofluorocarbons and the changes that can be expected in applying substitutes, weaning industries and consumers off CFCs will be difficult and costly. "There will be all sorts of impacts that most people do not yet appreciate," warns EPRI's Joyner. "They will range from the mundane, such as not being able to find a can of R-12 for your car on the store shelf, to the difficulty of choosing, with any confidence, the right cooling system for a commercial building you might be constructing."

Although an eventual total ban on CFCs is likely, only a 50% cutback by 1998 has been agreed to by international treaty so far. The first phase of this reduction, implemented by the new EPA rules that just took effect, rolls back national production to its 1986 level. This is to be reduced by 20% by mid-1993 and another 30% by mid-1998 to achieve a 50% cut from 1986 levels.

For now, a rollback in the United States to 1986 levels amounts to a 20% reduction from this year's projected production of over 425,000 metric tons of only the five main (of eight) restricted CFCs and halons, according to researchers at Oak Ridge National Laboratory (ORNL). Shipments of CFCs to U.S. refrigerator manufacturers reportedly are already on an allotment basis.

EPRI's Joyner notes that most other industrial countries party to the Montreal Protocol can fulfill their cutback to 1986 levels largely by eliminating CFCs from the least essential uses, such as aerosol propellants. Because the United States, Canada, and the Nordic countries banned most CFC aerosols in 1978, current cutbacks in these countries will more deeply affect CFC supplies and prices for more essential applications.

China and India—two nations with enormous latent demand for CFCs—and other developing countries are notably not parties to the Montreal Protocol. In China, for example, where production of consumer goods like refrigerators is just beginning, the use of CFCs is projected by 1998 to about equal that expected in the United States under the 50% cutback.

On a weight basis, a little more than half of the 1.54 billion pounds of ozone-depleting chemicals (including halons and some HCFCs) produced in the United States in 1985 was used as chemical solvents, mainly in the electronics industry. About 3.5% went into noninsulating foam, both flexible and rigid. A bit over 1% was made into fire extinguishants. Some 38% was applied in energy-related uses, such as refrigeration and building air conditioning (23.8%), mobile air conditioning (7.4%), and foam insulation (6.8%).

A somewhat different picture emerges when the 1985 U.S. production of the various chemicals is expresssed in equivalent pounds of CFC-11, one of the benchmark compounds for ozone-depletion potential. By that measure, energy-related uses swell to 41.5%, for example, and mobile air conditioning increases to 13.3%; fire extinguishants jump to 16.4% of the problem (because halon-1301 has 10 times the effect on ozone as CFC-11); and chemical solvents account for about a quarter of the ozone-depletion potential.

To implement the Montreal Protocol, the federal government is considering a rather complicated system of auctioned permits for CFC production rights and taxes on sales to allocate supplies by market forces to the most essential applications.

Effects on energy use

Because the energy-related uses of CFCs encompass both refrigerant fluids and blowing agents for insulation in buildings and appliances, the effect of cutting back on CFCs runs directly counter to recent government policies and manufacturers' efforts to increase energy efficiency in homes and businesses. Under most scenarios, the cutbacks also imply increasing demand for electricity.

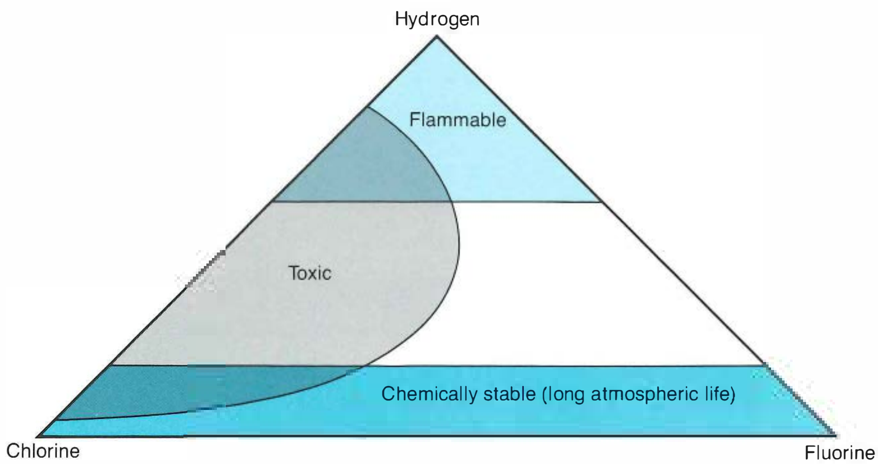
Over the long term, the changes wrought in vapor-compression equipment—its design, energy consumption, and cost—by reductions in CFCs could boost the economic competitiveness of nonelectric refrigeration and HVAC systems. But if the phaseout of CFCs spurs research and development of advanced technologies, a net gain, rather than a loss, in the efficiency of energy use in appliances and buildings could result, say some experts.

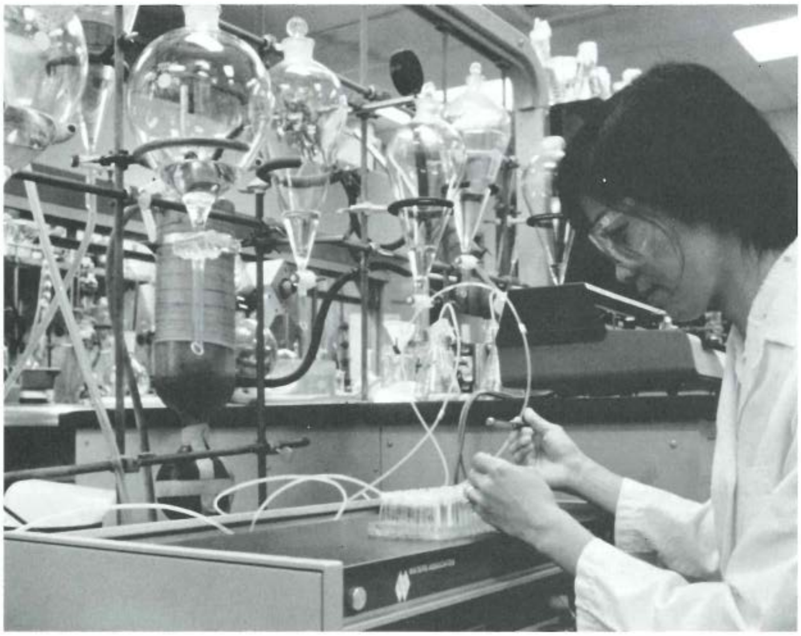
ORNL has analyzed energy use impacts of a possible CFC phaseout for the U.S. Department of Energy (DOE). To help guide R&D planning, the ORNL analysis considered a range of hypothetical scenarios to identify the limits of energy impacts, assuming the entire equipment stock conformed to the scenario.

One scenario assumed the ready use of all identified CFC alternatives as drop-in substitutes that would not require

Searching for Substitutes

The characteristics of modern refrigerant compounds depend largely on the proportions of hydrogen and the halogens chlorine and fluorine in their makeup. Methane (CH_4) is quite flammable, for example, while chlorine can make a compound toxic. Both chlorine and fluorine add chemical stability, a double-edged sword: stability makes for long-lasting refrigerant, but the stable chlorine-containing compounds don't break down easily when released to the troposphere and thus have more potential to deplete stratospheric ozone. The fully halogenated CFCs being cut back under the Montreal Protocol fall into the lower horizontal band of the composition/properties triangle. By adding hydrogen and reducing or eliminating chlorine from the molecules, CFC producers are working on alternatives that they hope will fall into the open area in the middle right of the triangle—little or no toxicity, low flammability, and moderate chemical stability. Refrigerants must also meet numerous thermodynamic and operational criteria.





redesigned equipment. A second scenario assumed that the preferred substitutes would not simply drop in for one reason or another and that a series of next-best or fallback alternatives, such as HCFC-22 and extruded polystyrene foam insulation, would have to be used in largely redesigned equipment and new buildings. In the worst case, the use of HCFCs as CFC substitutes was banned, the production of extruded polystyrene was sharply limited, and ammonia and propane became the principal refrigerants used. (The worst case did not include a ban on HCFCs in current applications, which would have an even greater effect on energy use.)

ORNL analyzed the effects of alternative refrigerants and insulation on energy use for the current national stock of a range of building equipment (including refrigerators, water heaters, and chillers) and building envelopes, as well as mobile refrigeration and cooling systems in transportation. The findings suggest that across all these applications and sectors, the national energy impacts of CFC alternatives could range from a penalty of as little as 0.21 quad/yr (1 quad = 10^{15} Btu) if drop-in CFC substitutes became available (an unlikely prospect), to about 1 quad/yr under the scenario of fallback alternatives, to as much as 2.18 quads/yr under a worst-case scenario. (About 76 quads of primary energy are consumed annually in the United States by all applications.)

On the other hand, if sufficient R&D were applied to bring about advanced technologies, a gain of as much as 0.83 quad in overall national energy efficiency might be achieved, says ORNL. Six-tenths of a quad could be saved by the development and use of vacuum-insulated refrigerators, freezers, and water heaters. Further savings would be possible through advanced insulation for buildings and refrigerated trucks or through advanced refrigeration cycles.

Looking just at the electricity-powered applications in the building equipment sector that includes refrigerators and freezers, cold-drink vending machines, retail refrigeration, and water heaters, the effects on electricity use of the different CFC phaseout scenarios range from an increased demand of 13 billion kWh/yr under the near-term drop-in substitute scenario, to 56 billion kWh/yr with fallback alternatives, to over 94 billion kWh/yr under the worst-case hypothesis. In contrast, a series of advanced technology solutions might reduce electricity demand by more than 53 billion kWh/yr. (Electricity generation in the United States in 1988 totaled 2701 billion kWh.)

But, as EPRI's Joyner notes, none of the ORNL scenarios were intended to be realistic—rather, they are limiting cases. In any event, the changes would actually take place over a decade or more. The scenarios do not address the complication of how fast the present U.S. manufacturing capacity for HVAC and refrigeration systems could realistically turn out new equipment based on as-yet-unidentified but environmentally safe CFC alternatives; nor do they address the economic cost of such a widespread replacement.

"None of the Oak Ridge scenarios represents what will actually or probably happen," says Joyner. "The cost effects of different scenarios will be highly dependent on how fast the phaseout of CFCs is actually carried out. This dimension is not analyzed, but as ballpark boundaries on the magnitude of potential effects, the results suggest there will be substantial energy impacts."

In addition to the effects on energy use of CFC rollbacks, utilities will also be directly affected by the somewhat later phaseout of halon gas fire extinguishers. The unique ability of halons to snuff out an explosion in progress while leaving no harmful residue has made them ideal as close-quarter, critical-facility fire extinguishants on aircraft and ships, in computer rooms, and at electric power facilities. Developing satisfactory alter-

CFCs and Modern Refrigeration

The history of the development of CFC compounds is fraught with irony. Although vapor-compression refrigeration dates back to the mid-nineteenth century in England, it was not until the late 1920s in America that the shortcomings of the coolants used in early home refrigerators spurred a corporate research laboratory to look for a better refrigerant.

Before CFCs were invented, the most common refrigerants were ammonia, carbon dioxide (CO_2), ethyl chloride, isobutane, methyl chloride, methylene chloride, and sulfur dioxide (SO_2). All had disadvantages. Although safest to use, CO_2 must operate at high pressure and thus requires equipment of heavy construction. Isobutane is relatively nontoxic but highly flammable. Ethyl chloride, methyl chloride, and methylene chloride are all toxic. Ammonia and SO_2 are highly noxious as well as toxic.

But most industrial and commercial applications of refrigeration and air conditioning managed to live with the limitations of coolants that were otherwise desirable for their thermodynamic properties, such as critical-point and boiling-point temperatures and vapor heat capacity. Chillers at ice-making and cold storage plants and breweries in the industrial and heavy commercial sectors were quite satisfied with ammonia, which is still widely used. Comfort-conditioning and industrial air-conditioning systems typically used ammonia, SO_2, or methylene chloride, although in the 1920s few homes or small businesses yet enjoyed air conditioning.

But quite a lot did have refrigerators, which increasingly replaced the older icebox-type units. The largest manufacturer of household and light commercial refrigerators in those early years of the burgeoning market was

Frigidaire, a subsidiary of General Motors. All of Frigidaire's units used SO_2 as the refrigerant. Although the most toxic of the then-available coolants, SO_2 is sufficiently noxious to awaken someone from a deep sleep. Even small leaks indoors will prompt nauseous reactions among people and lead to rapid evacuation of a building; because of this, deaths or injuries from leaks were rare.

Some early refrigerators used isobutane, leaks of which sometimes caused fires. Others used one of the sweet-smelling but toxic chloride gases. The few cases in which serious leaks of those refrigerants caused death or illness were widely and sometimes sensationally reported. Public alarm and politicians' calls to ban refrigerants were fanned by negative publicity from the ice industry, whose icebox business was threatened by refrigerators.

Despite the fact that Frigidaire refrigerators did not use the refrigerants involved in most of the casualties, at GM's corporate research laboratory in 1928, a team headed by Thomas Midgley, Jr., was told that "the refrigeration industry needs a new refrigerant if it is ever going to get anywhere." Midgley and his associates, Albert Henne and Robert McNary, turned to the periodic table in their search for a nontoxic, nonflammable, and effective working fluid for the home refrigerator.

By eliminating chemicals that were unstable, were insufficiently volatile, or had too low a boiling point, Midgley's crew was left with eight elements: carbon, nitrogen, oxygen, sulfur, hydrogen, and the halogens fluorine, chlorine, and bromine. Further considerations of flammability and toxicity pointed in the direction of fluorine compounds.

At the outset, Midgley suspected that a mixture of a nontoxic but flammable chemical with a nonflammable but toxic one might turn out to be nonflammable and only moderately toxic. The additional requirement that the refrigerant be chemically inert and stable focused attention on the strong carbon-fluorine bond of certain carbon-based compounds—specifically, the fluorocarbons (also known as halocarbons), a group of 19 compounds, including CFCs and bromine-containing compounds.

Fluorocarbons are chemically similar to hydrocarbon molecules, except that one or more hydrogen atoms are replaced by chlorine, fluorine, or bromine atoms. CFCs are fully chlorinated fluorocarbons, meaning that they have no hydrogen atoms—only chlorine, fluorine, and carbon.

Ignoring conventional wisdom and acting on a hunch that it might be nontoxic, Midgley and his associates settled on dichloromonofluoromethane. Within three days of this selection, they had synthesized a small quantity and decided that it was of low acute toxicity. Several years of investigation of a number of CFC compounds followed; Frigidaire wanted all possibilities explored before filing for patents. Among those identified and produced was dichlorodifluoromethane, which differed from the original compound only by an additional fluorine atom.

Midgley's team had arrived by a combination of insight and intuition at the most ideal refrigerants possible, it seemed. They could be readily and cheaply made in a one-step reaction using carbon tetrachloride. Nontoxic and, owing to the complete lack of hydrogen, nonflammable and extremely stable and unreactive, the compounds were immediately hailed as wonder chemicals.

CFCs were dramatically introduced to the world in 1930, when Midgley stood before a meeting of the American Chemical Society, inhaled a volume of dichlorodifluoromethane, and extinguished a candle. The choice was fortunate. The original CFC synthesized, dichloromonofluoromethane, was later shown to cause severe organ damage under chronic exposure.

Today, two of the principal CFCs being cut back under the Montreal Protocol are trichlorofluoromethane and dichlorodifluoromethane. Under an arcane code based on the numbers of chlorine and fluorine atoms, they are commercially sold as R-11 and R-12, respectively, by various producers under a variety of trademarks, including Freon (by Du Pont) and Genetron (by Allied-Signal). They and related compounds are made and used around the world.

Although invented to serve the residential refrigerator market, CFCs were actually first applied in the commercial sector, where Frigidaire used R-12 in ice cream cabinets. The new refrigerants did not turn up in Frigidaire's household refrigerators until 1933, the same year Carrier introduced R-11 in centrifugal compressors for air conditioning. By the late 1930s, methylene chloride had disappeared from household machines, but it continued to be used in light commercial applications into the 1950s. Wide use of SO_2 continued into the 1940s.

Today, R-11 (or CFC-11) is used mostly as a refrigerant in large centrifugal compressors and chillers and as a foam-blowing agent for insulation and packaging. R-12 (CFC-12), the compound Midgley inhaled, is the coolant in all domestic and most supermarket refrigerators and in all automobile air-conditioning systems. Related compounds are used in nearly every other vapor-compression device, including home and office air-conditioning systems, and as industrial solvents. □

natives to halon fire extinguishers reportedly is proving to be even more challenging than developing CFC substitutes.

As part of its rules implementing the Montreal Protocol, the EPA has allocated production rights to CFC manufacturers and has proposed a fee system to prevent windfall profits as supplies of the chemicals tighten and prices rise. Manufacturers, meanwhile, contend that such profits should be used to finance the development of CFC alternatives and the facilities to produce them. For the near term, however, higher refrigerant prices are a trifle compared with the longer-term implications of redesigning equipment and systems for as-yet-unidentified CFC alternatives.

The cost of refrigerant (until recently less than $1 a pound) accounts for less than 1% of the equipment cost of most vapor-compression systems and an even smaller percentage of the installed cost. Refrigerant prices for most applications could rise considerably before significantly affecting overall system costs. On the other hand, the energy impacts associated with restrictions on CFC-blown foam insulation, as well as the cost implications of foam alternatives, are expected to be significant.

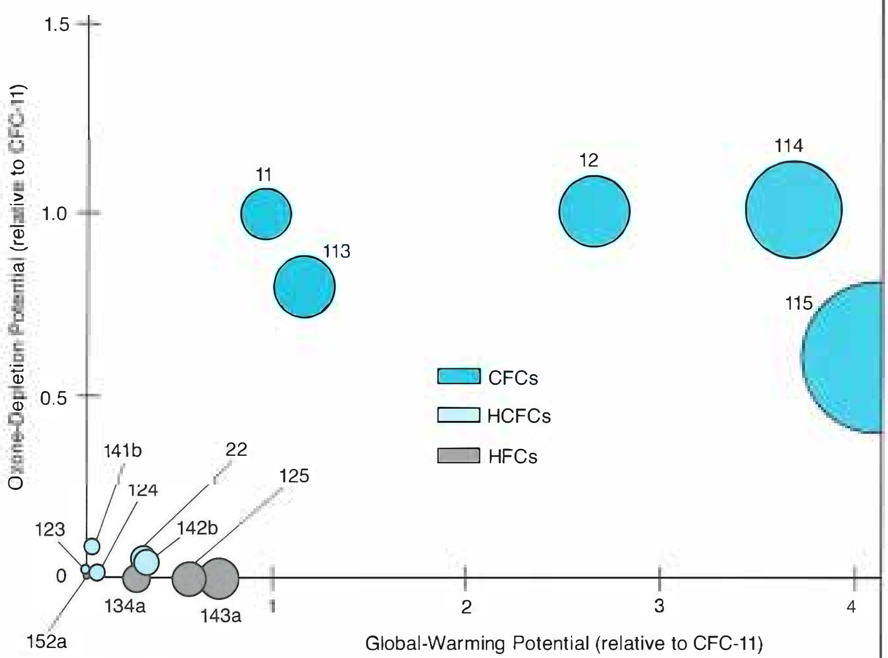
But the real threat to electric utilities is longer term. As less efficient CFC alternatives are identified and as redesigned (and presumably more expensive) equipment to use them reaches the market, the higher installed and operating costs of that equipment could boost the economic competitiveness of alternatives to vapor-compression cycles. The principal rival in the wings for commercial and industrial applications is the gas-fired absorption chiller, whose cost and performance have been improving as a result of several years of substantial R&D support from DOE and the gas industry.

Absorption chillers represent a double threat to much of the commercial refrigeration and air-conditioning load now served by electricity. Not only might they replace the electrically driven vapor-compression cycle with thermal cycles, they provide a year-round application for the waste heat from cogeneration (the simultaneous production of process steam or heat and electricity). A use for this waste heat is a key factor influencing the cost-effectiveness of commercial cogeneration.

A commercial builder, for example, might consider the trade-offs between the availability and the eventually higher operating costs of vapor-compression-based centrifugal chillers, on the one hand, and the perhaps eventually competitive cost of cogeneration coupled with absorption chillers, on the other. Either choice would probably commit that building's energy load for 20 years or more, possibly for the life of the building.

Double Danger From CFCs

Fully halogenated CFCs and many of the compounds being considered as alternatives have the potential both to deplete stratospheric ozone and to contribute to possible global greenhouse warming through the absorption of infrared energy. In this graph, the ozone-depletion and global-warming potentials are represented for various compounds relative to CFC-11, which is given a value of 1 on both axes; the circles are proportional in area to the compounds' atmospheric lifetimes. The fully halogenated CFCs have long lifetimes and considerable potential to contribute to both problems. The hydrochlorofluorocarbons (HCFCs) break down much faster in the atmosphere and therefore have only about 2–5% of the ozone-depletion potential of CFCs. The hydrofluorocarbons (HFCs) contain no chlorine to threaten stratospheric ozone, but they do have some potential to act as greenhouse gases.



Source: Du Pont

Looking ahead

"The electric utility industry could lose much of the refrigeration and cooling business in the next 5 to 10 years if solutions to the problems posed by the phaseout of CFCs do not become available," warns EPRI's Arnold Fickett. "This is not a future issue that we can study for a while, like global warming. This is a today issue. But it's clear that whatever the solutions, the cost of refrigeration is going to go up."

Fickett and Joyner hope that, for the near term, some degree of rationality will prevail on the international and domestic policy fronts as CFCs are phased out—permitting, for example, the temporary, stepped-up use of HCFC-22 where it can serve as a close CFC substitute until a more acceptable alternative or mixture is developed. Meanwhile, pragmatic realities may force a relaxation or postponement in the pace of mandated federal appliance energy-efficiency standards, which, though long in coming, now conflict with CFC-related constraints on product design.

Joyner points out that the overall economic cost of a phaseout is closely related to the speed of change. "My feeling is that somewhere along the way there will be an accommodation in the timing of the CFC regulations and appliance efficiency standards. The lower-valued uses of CFCs, such as in foams and as solvents, are likely to be affected first. One major development that will help stretch shrinking CFC supplies is the emergence of refrigerant recovery and recycling practices for existing equipment in the service market, which accounts for the majority of demand for CFCs."

Transition and turmoil will mark the next decade for manufacturers and users of refrigeration and cooling equipment, as well as for those involved in non-energy-related applications of CFC compounds. Although CFC producers have been hard at work on a new generation of refrigerants, equipment manufacturers have only recently begun to follow suit.

EPRI support of R&D in response to the cutback or phaseout of CFCs has been limited by funding availability. But as noticeable effects on utility customers loom in the near future, EPRI's Customer Systems Division has begun several related activities. In addition, the Environment Division plans to monitor the evolving atmospheric science aspects of the CFC-ozone issue.

To complement the chemical industry's development of near-term CFC alternatives, EPRI is cofunding work with the EPA on candidate backup compounds. Researchers at Clemson University and at the University of Tennessee are carrying out related efforts to synthesize and characterize small quantities of new alternative refrigerants and foam-insulation-blowing agents. The chemicals being evaluated were earlier identified as promising by an EPA-convened expert panel. It will be left to industry to pursue the full development and testing of these compounds if any of the primary alternatives fail to meet the essential criteria.

EPRI is also supporting work at the National Institute of Standards and Technology (formerly the National Bureau of Standards) to explore the potential of new mixtures of refrigerants for providing improved efficiencies and low-temperature performance as working fluids. Blends of refrigerants that individually have certain undesirable properties may represent a new category of remedy.

Cofunded with New England Electric, a scoping study is under way to define advanced domestic refrigerator and freezer design options and development plans. The goal is to pursue collaboration with the home appliance industry on new technology and product development. EPRI also plans to sponsor the development of advanced commercial chillers based on environmentally safe refrigerants.

EPRI is continuing efforts to alert utilities to the coming problems posed by the changes stemming from the Montreal Protocol to protect the ozone layer. A utility seminar-workshop on the subject, cosponsored with New England Electric, is planned for November 8–9 in Boston.

Despite the world spotlight on the ozone issue, the outlook for a future without CFCs remains clouded in uncertainty and ominous in potential impact, with doubtful prospects for quick or painless resolution. The effects of turning down or closing the valves on a family of chemical working fluids that are the lifeblood of modern cooling systems have only begun to be felt. ■

Further reading

"Producers, Users Grapple With Realities of CFC Phaseout." *Chemical and Engineering News*, Vol. 67, No. 30 (July 24, 1989), pp. 7–13.

"Concern Over Ozone." *EPRI Journal*, Vol. 14, No. 4 (June 1989), pp. 14–21.

Steven Fischer and Frederick Creswick. "How Will CFC Bans Affect Energy Use?" *ASHRAE Journal*, Vol. 30, No. 11 (November 1988), pp. 30–34.

Bernard Nagengast. "A Historical Look at CFC Refrigerants." *ASHRAE Journal*, Vol. 30, No. 11 (November 1988), pp. 37–39.

Robert Pool. "The Elusive Replacements for CFCs." *Science*, Vol. 242, No. 4879 (November 4, 1988), pp. 666–668.

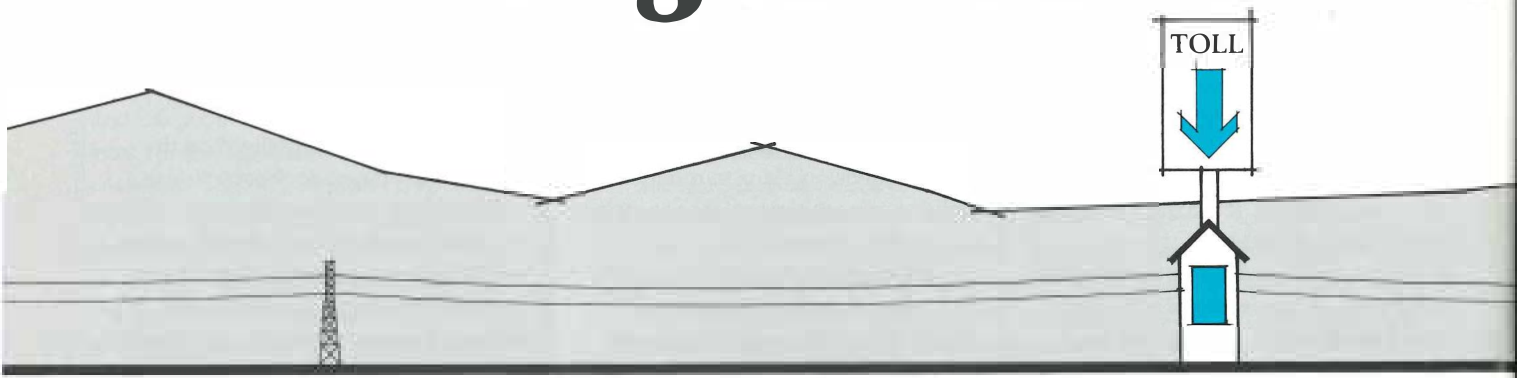
Mark McLinden and David Didion. "CFCs: The Quest for Alternatives." *ASHRAE Journal*, Vol. 29, No. 12 (December 1987), pp. 32–42.

"CFCs: Is the Sky Falling?" Special report. *ASHRAE Journal*, Vol. 29, No. 11 (November 1987), pp. 21–39.

Conference announcement The impacts of CFC restrictions on electric utilities will be explored at a two-day seminar November 8–9 at the Charles Hotel in Cambridge, Massachusetts. Cosponsored by New England Electric and EPRI, the conference will provide background as well as updates on industry developments, regulatory actions, advanced technology, and utility impacts. Workshops will cover the most immediately affected end-use areas: refrigerator/freezers, centrifugal chillers, and commercial-industrial refrigeration systems. The seminar is open to EPRI members and government, academic, and nonutility attendees. For program, registration, and accommodation information, contact Maryalice Fischer, New England Power Service, (508) 366-9011, extension 2353, or Tania Jemelian, EPRI, (415) 855-2810.

This article was written by Taylor Moore. Technical background information was provided by Powell Joyner, Customer Systems Division.

Taking the Measure of



How much use is the neighboring utility making of your transmission lines? Studies have shown

of the flows of power through complex networks in real time and

Competition is growing in the bulk power market, driven not only by cogenerators and independent producers but also by increasing electricity sales between utilities. From a utility operations perspective, these forces are converging on the industry's transmission network.

The wheeling of power between buyers and sellers through the intervening high-voltage systems of other utilities has grown at a rate exceeding the rate of growth of both load and generating-capacity additions in the last decade. In turn, so have loop flows of power among neighboring and nearby utilities. Such parallel flows in transmission networks result from a property of electricity that causes it not to take simply a direct path between buyer and seller, but to divide among all available paths in inverse proportion to individual circuit impedances.

Loop flow has always been a problem to utilities, even before the competitive and power-wheeling 1980s. Technology was not available to control these flows. Flows between adjacent systems, to the extent they were known, were compensated for in trade. There were adequate capacity reserve margins on most transmission systems. And the regular addition of new transmission capacity helped push potential bottlenecks further into the future.

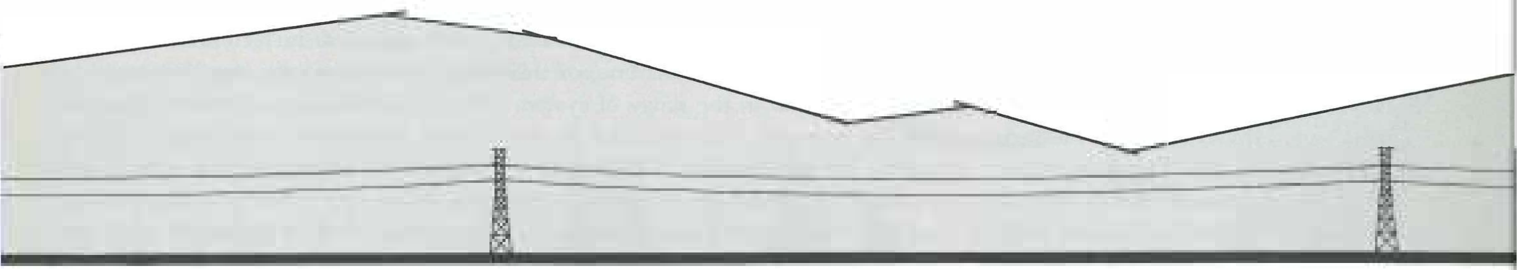
Now, with higher-voltage, lower-impedance lines and a larger number of intersystem transfers taking place on the transmission system, loop flows exacerbate the situation even more. Transmission systems—their expanded function, access to use them, and control of their operation—are now in the spotlight of the competition and deregulation afoot in the electricity supply industry.

Increasingly, transmission systems are being recognized by utilities and regulators alike as strategic assets. A critical link in the electric power system, transmissions systems are coming to be seen not just as the best way to get megawatthours from point A to point B, but as a resource to be more aggressively marketed and efficiently managed in order to generate more revenue.

The problem has been that loop flows were difficult to measure or to calculate accurately. Most available methods in use are off-line, as an after-the-fact analysis of a particular time under specific conditions. The many powerful computers driving utility power system control centers now provide continuous, on-line monitoring and some automatic control of key transmission system facilities. But these massive energy management systems were not designed to calculate for system operators exactly how much of whose power is flowing over a specific circuit at any given time.

Because of the relevance to several converging developments, including a potential for new forms of transmission service to become an important source of revenue in an era of increased power wheeling and dealing, EPRI recently examined available and potential methods of measuring transmission system use and accounting better for power transfers on utility systems. The bottom line from a pair of studies by Casazza, Schultz & Associates (CSA) is that with minor modification to control center software, power transfers could be tracked and tabulated on-line, automatically, every hour or even more frequently, if needed. Where power transfers can be measured, an opportunity exists for utilities to gain additional earnings and add to their profitability.

Transmission Flows



hat with minimal modifications, control center software can keep track

/ith surprising accuracy.

Charting actual power flows

In simpler times, charges for transmission service in interutility transactions were calculated solely for a contract path, assuming for the sake of simplicity that the power flowed on the lines directly connecting the buyer and the seller. The contract path became the method most often used for calculating such charges.

But some state regulatory bodies have begun moving away from the concept of a contract path. Georgia's utility regulators simply allocate percentages of the state's total calculated costs of transmission to utilities in proportion to their contribution to total generation. For several years, Texas utilities have annually conducted a statewide load-flow analysis by computer to determine flows over key interconnections for regulatory and planning purposes.

The CSA studies showed that some utilities and power pools have begun to pioneer the measurement of loop flows online. The New York Power Pool (NYPP) and the Pennsylvania–New Jersey–Maryland pool (PJM), for example, periodically assess interpool flows on-line using actual operating data. Accounts are settled according to the sum of net loop flows over specified periods. Over the preceding three years, NYPP paid PJM $31 million as half payment for measured loop flows. The remainder of the debt will be taken as banked megawatthours owed by the New York pool to PJM, to be delivered according to agreed-upon terms.

"As the number and frequency of bulk power transactions that cause loop flows increase, it has become more important to deal with how power actually flows," notes Robert Iveson, technical adviser in the Electrical Systems Division.

A series of questions are increasingly being asked of and by power system operators and their utility companies. How much is their transmission system being used, by whom, and for what purpose, now and over time? What actually constitutes use of the transmission system? And what is the theoretical maximum use that can be made of a transmission system, taking into account the usual considerations of circuit thermal limits, system voltage, transient stability limits, margins for contingency, and the like? The same questions can be and are being asked about and by interconnected utilities in power pools, which operate their generation and transmission systems as a coordinated, integrated unit.

The questions are also the focus of the pair of studies conducted for EPRI by CSA. The first looked at different ways to measure transmission system use, including methods currently used by utilities or proposed, as well as theoretical possibilities. Actual system data from five utilities were used in assessing the alternative approaches.

The second study identified the potential for on-line methods for determining the level of transmission system use. New approaches include expanding the portion of an interconnected high-voltage system monitored by a utility or pool control center computer to include all important external sources or transactions that might affect internal power flows.

Regression analysis techniques similar to those already programmed into power system state estimators at control centers may also be used to determine the impact of unobservable users of a transmission system. Observable circuit loadings and assumed system response to specified transactions or flow patterns can be used to infer the source of unobservable flows. System response factors can be predetermined, or determined by regression analysis, from changes in the loadings on observable circuits. (The term *unobservable* is used to describe a flow, load, or generator output that is not metered by or available to a specific control center.)

The powerful state-estimator programs running on utility control center computers now use regression analysis to regularly and routinely calculate loadings on circuits and substations, voltages, interchange levels, and other key operating data from a limited set of data on the output of individual generators and the flow of current through substation transformers. The CSA studies identified this technique's potential to handle the even greater demands of on-line analysis of bulk power transactions.

Methods now in use

Engineers have long used various techniques to evaluate transmission use and the availability of transmission capacity. Off-line methods, first developed for system planning, have included network load flow and voltage studies; steady-state, transient, and dynamic stability studies; and detailed reliability calculations. But these yield snapshot pictures of the flows that could be expected under specific conditions and circumstances.

The principal approach presently used for determining transmission system capacity is to calculate what is known as transfer capability. National and regional industry guidelines exist for such calculations, and system limits are published at least twice a year. But as with off-line methods, transfer capabilities are usually determined for a specific set of conditions and equipment outages or contingencies. In actual operation, a system's transfer capability is continually changing as loads fluctuate, generation dispatch varies, and specific facilities in service change.

Some utilities are developing and using new measures that incorporate one of several broad indexes of transmission use based on average loading or duration of loading on key or limiting facilities. These new measures include, for example, loading-to-capacity ratio, the megawatt-mile method, line loadability, and probabilistic techniques.

The measures may differ in the portion of a utility system they consider, such as a key interface, an individual line, or the full system, and in the range of system limits or potential contingencies they can handle. But such indexes are beginning to be used by some utilities to quantitatively evaluate the effective use of transmission system investment and the amount of reserve transmission capacity as it changes over time.

The measures can help determine how much transmission capacity may be available in the future for system loads or for use by other parties, and may possibly help identify niche market opportunities. (In the recent merger of Utah Power and Light with PacifiCorp, the Federal Energy Regulatory Commission specified transmission access conditions and required the merged company to specifically determine the transmission capacity available for three different types of interutility transactions.) The methods are also valuable for assessing the potential for new technologies, such as those involving power electronic devices, to improve overall operation of transmission systems.

Several utilities or power pools, including PJM, NYPP, Public Service Electric & Gas, and the Bonneville Power Administration, now use the loading-to-capacity ratio in reporting transmission assessment. Megawatt-mile methods are used by utilities in Texas and by the PJM interconnection, and are also being used in other countries. The loadability method, used for evaluating a key interface, is being applied by the American Electric Power system. Probabilistic methods have been developed by EPRI and by AEP and other utilities.

In the EPRI-sponsored study of the methods, CSA analyzed what actually constitutes transmission capacity. Calculations of transmission use that fail to take into account provisions for forced and scheduled outages, system load factors, and generation capacity reserves for reliability, for example, will show unrealistic and inaccurate low loadings.

CSA analyzed the factors that limit the maximum reasonable use that could be made of a transmission system. The maximum theoretical base ratio was estimated for comparison with actual loading-to-capacity ratios calculated using operating data from five actual utility systems.

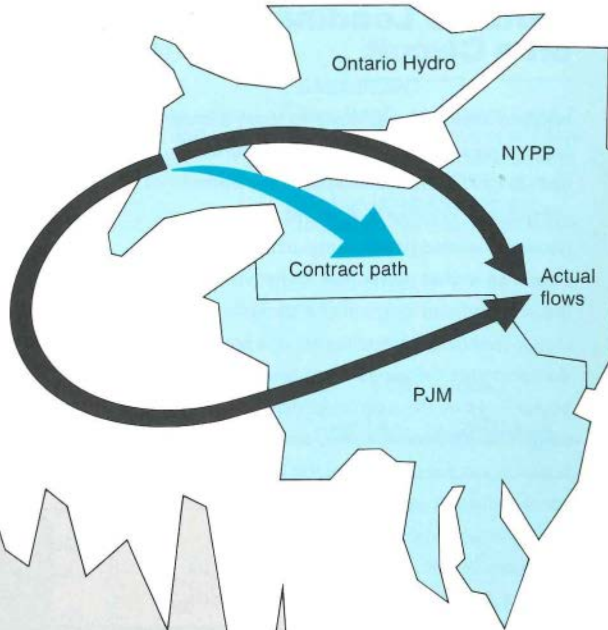
The results highlight the limits of the use of such measures. For example, for one utility, the calculated transmission system loading-to-capacity ratio averaged for all circuits (based on normal ratings) over all hours of the year, without provision for contingencies, was just under 24%. But when that same index is determined by calculating an estimated maximum theoretical potential loading of 39%, the loading-to-capacity index climbs to 61%. For both cases, the loading numbers go progressively higher when calculated for daily, weekly, monthly, and annual peak load hours; for specific limiting facilities, such as transformers; or with provisions for contingencies.

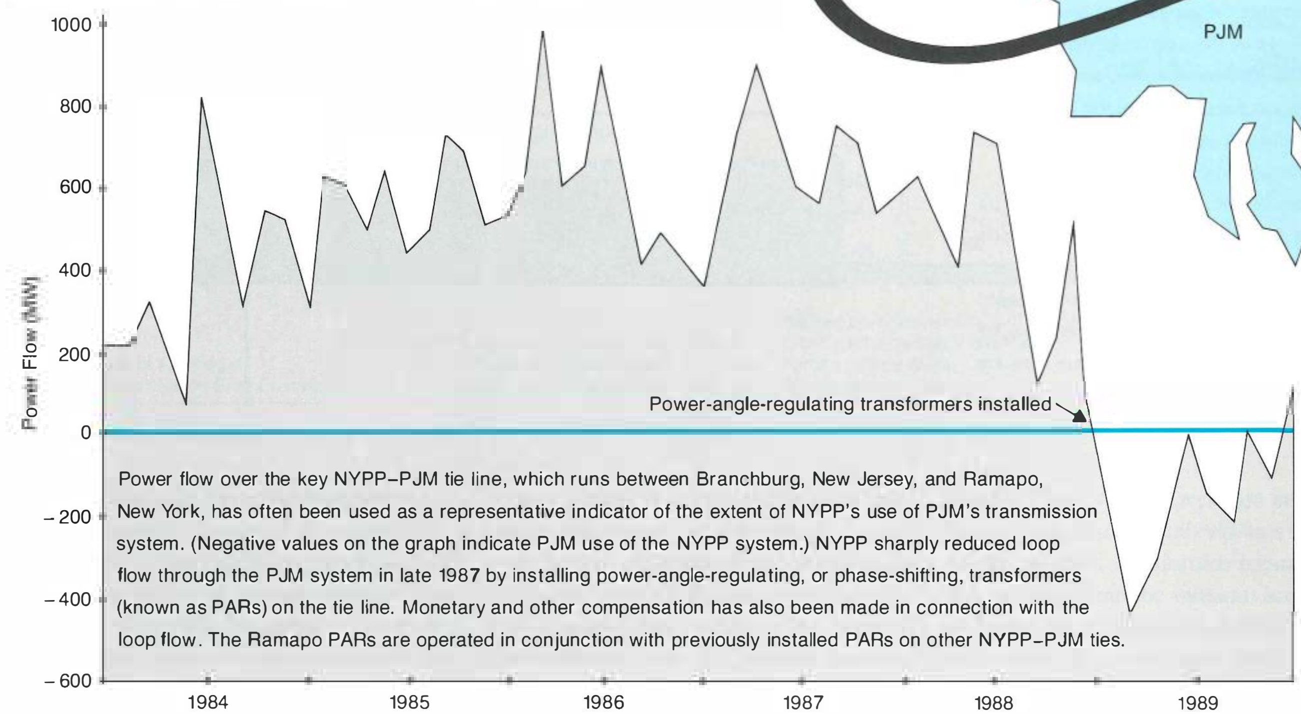
"Regardless of what type of transmission use measure is applied, comparisons of indexes for different systems could be misleading. For instance, a system with a lower use index is not necessarily more able to provide transmission service, or making poorer use of the capital investment in transmission, than systems with higher indexes," notes CSA's Jeffrey Palermo, a principal investigator for the study.

"Analyses of the sample systems clearly showed that transmission indexes can be useful, but only if they are developed with a clear recognition of how they will be used," Palermo adds.

A Case Study in Loop Flow

A good example of how loop flow has been resolved by two large interconnected power pools involves the New York Power Pool (NYPP) and the Pennsylvania–New Jersey–Maryland (PJM) Interconnection. Throughout the early 1980s, loop flow on the PJM transmission system increased as NYPP imported increasing amounts of electricity from Ontario Hydro in Canada. Although the contract path for these power purchases follows direct ties between NYPP and Ontario Hydro, some of the power actually flowed into the NYPP system by way of the PJM system. Conversely, a power transfer from the east-central region to PJM increases loading on the NYPP system.





Power flow over the key NYPP–PJM tie line, which runs between Branchburg, New Jersey, and Ramapo, New York, has often been used as a representative indicator of the extent of NYPP's use of PJM's transmission system. (Negative values on the graph indicate PJM use of the NYPP system.) NYPP sharply reduced loop flow through the PJM system in late 1987 by installing power-angle-regulating, or phase-shifting, transformers (known as PARs) on the tie line. Monetary and other compensation has also been made in connection with the loop flow. The Ramapo PARs are operated in conjunction with previously installed PARs on other NYPP–PJM ties.

Going from off-line to real time

While CSA found that methods now used by some utilities can determine power transfers and accurately indicate the level of transmission use, virtually no utility is today able to conveniently and continuously monitor those flows or indexes in real time as they change with system conditions. Nor is any method today able to ascribe specific power flows to specific sources, differentiating those internal to the system from those of external origin. A follow-on study by CSA judged both developments feasible.

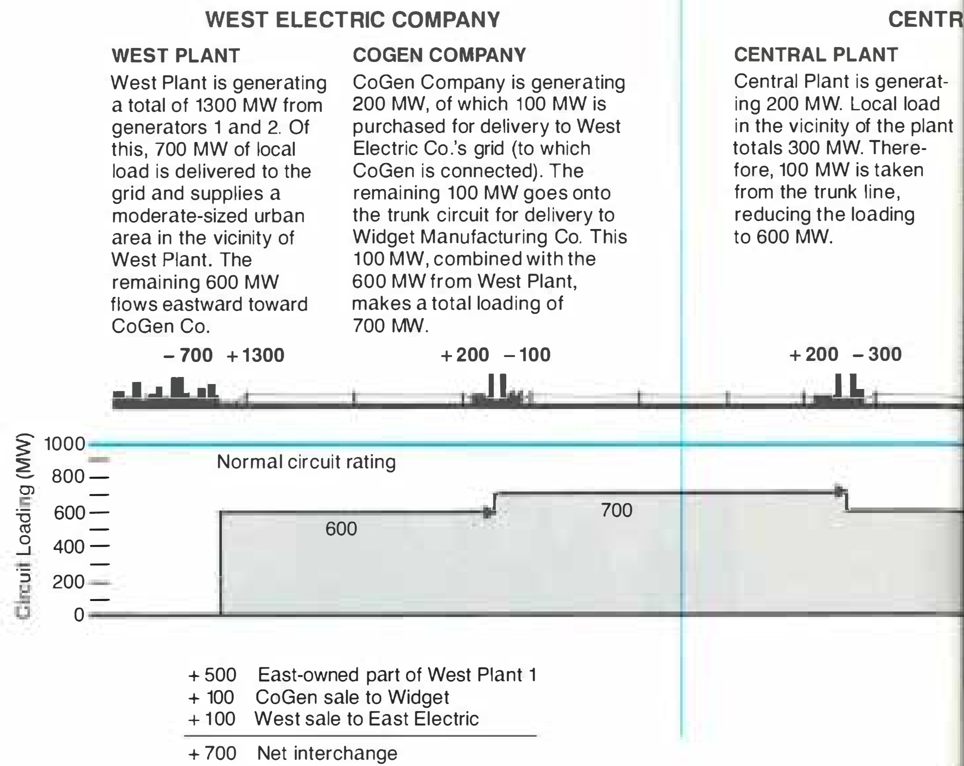
To a significant degree, both extension of present capabilities for determining transmission use and identification of specific users will depend on the successful integration of utility communications systems under accepted common protocols and data standards. Several industry efforts, including an EPRI project, are focused on this long-term initiative. At least two groups of utilities—one in the East and one in the West—have begun laying the groundwork for defining technical and information standards for a new dimension of high-volume interutility system data exchange.

Greater sharing of on-line operations data by utilities is the key to one of the principal approaches to determining transmission use by sources or systems outside the monitored system control area. Strengthened communications links and standardized protocols and data formats are expected to lead to a greatly improved ability on the part of utilities to access and incorporate more extensive data from neighboring systems in their on-line network control computers.

In addition to the technical challenges of expanding the monitored control area, greater intersystem communication raises issues of data security and proprietary business information, which companies that compete directly in the bulk power market may grow more reluctant to share. "The sharing of operating data in an increasingly competitive business is

Variable Loading on a Circuit

Keeping track of power flows on today's transmission networks is complicated by transactions involving the wheeling of jointly owned utility power, cogenerated power, independently generated power, and purchased utility power, as well as power flow for native load. A greatly simplified diagram of a transmission circuit spanning three utility service areas demonstrates the variability of loading, or the power flows on the system, at different points as generators and loads add and subtract power along the distance of the line. Control center software constantly updates the status of key network parameters and flows, but operators do not now have the on-line capability for monitoring and quantifying the portions of actual power flow over a particular circuit attributable to specific users. Recent studies for EPRI confirmed the potential for adding such a capability to system software.



a serious concern," notes EPRI's Iveson. "Utilities might borrow a practice from the financial community, with its 10K reports, and require standard technical data on each other's transmission system. If all utilities were required to disclose necessary technical data, no one would have an unfair advantage."

An alternative to expanding the monitored control area that may become more important if competition reduces data sharing among systems is the use of regression analysis techniques. With observable system data and only limited data from external systems, regression analysis can determine an unobservable user's impact on a transmission system. The computational techniques are similar to those incorporated in control center state-estimator programs, which every few minutes determine key transmission system parameters from a limited set (which may still total several thousand points) of system data.

With such on-line data on the observable system and predetermined unobservable system response factors, regression analysis offers a means of inferring the changes in observable system flow patterns that result from changes in loading on unobservable systems. Response factors for the unobservable system may be defined by a separate off-line study, estimated on the basis of other systems, determined on-line with data from key unobservable facilities, or determined by further use of regression analysis based on knowledge of the unobservable system's net imports or exports or its area control error.

For a utility with a modern system control center, the cost of additional communications hardware and software for expanding the monitored control area or the cost of new software to determine transmission use by regression analysis must be weighed against possible increases in revenue, according to CSA's Palermo. If the NYPP–PJM case can serve as a guide, the potential revenue to be gained from being able to quantify and charge for loop flows outweighs the cost of the required additions for monitoring.

Assuming the communications links, data, and software become available and are in place, power system researchers envision a not-too-distant future when operators and control center computers will handle bulk power transactions routinely on-line. With the push of a button, according to this scenario, the operator could request a transaction. The console screen would immediately identify all affected transmission circuits and determine the availability of transmission capacity. Using utility-specific data, the costs of flows over all affected circuits would be summarized electronically.

Another push of a button could cause the control system computer to execute the desired transaction, adjusting generation and flows as needed and reporting the transaction to all affected parties. Billing and accounting functions could also be automated for such transactions.

"Close monitoring of the flow of power on the electric utility system is essential not only to minimize the cost of loop

-ECTRIC COMPANY

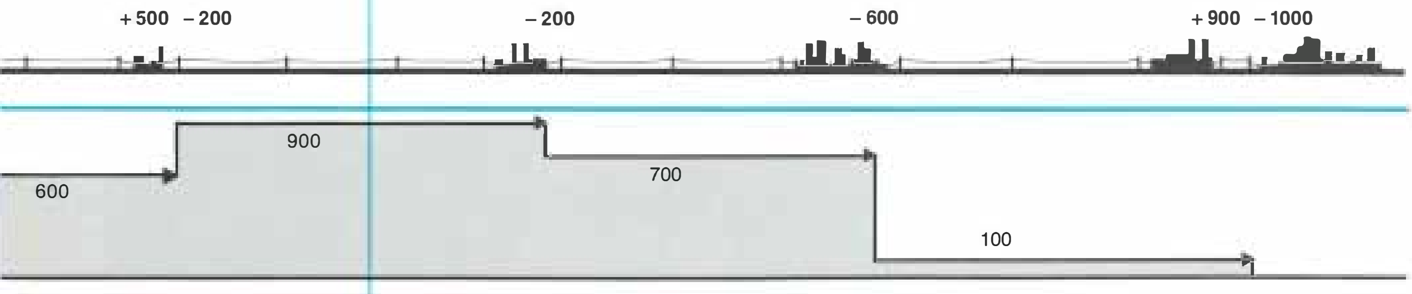
INDEPENDENT POWER PRODUCER COMPANY
Independent Power Producer Co. (IPP) is generating 500 MW, of which Central Electric Co. purchases 200 MW to supply Central's network. The remaining 300 MW combines with the 600 MW line flow, resulting in a trunk line loading of 900 MW.

EAST ELECTRIC COMPANY

WIDGET MANUFACTURING COMPANY
Widget Manufacturing Co. has contracted to buy 200 MW, of which 100 MW is provided by CoGen Co. and 100 MW by IPP. This reduces the line loading to 700 MW.

EAST CITY
East City is a fairly large city of half a million population and represents a load of 600 MW. Line loading is reduced to 100 MW.

EAST PLANT
East Plant's generators 1 and 2 are producing a total of 900 MW. This generation, combined with the line flow of 100 MW, supplies an urban load and surrounding area totaling 1000 MW.



+ 100 IPP sale to Widget
+ 100 Central sale to East Electric

+ 200 Net interchange

− 200 Widget purchases from CoGen and IPP
− 500 From jointly owned West Plant 1
− 100 Purchase from West
− 100 Purchase from Central

− 900 Net interchange

flows, but also to improve system performance and efficiency," says Neal Balu, program manager of the power systems planning and operations program. "Accurate measurements will ensure that the fast-acting controllers envisioned in our flexible ac transmission system (FACTS) strategy will provide maximum system utilization."

The next steps

CSA identified a number of areas for EPRI to consider for further research. For example, more extensive analysis of the data from the five utility test systems, comparing all of the calculation methods, may yield even greater insight into their potential. A deeper look at the approaches to determining maximum theoretical transmission use as well as the data collection and verification requirements of the various measures could prove fruitful.

New methods for on-line calculation of transmission use need to be tested and implemented on an actual operating system. Doing this first for a small system or a small part of a larger system may reveal further information on the benefits and difficulties. The accuracy of regression analysis for determining external system transactions and system response factors should be further tested, according to CSA.

"The studies identified several remaining uncertainties, including such practical questions as how many lines would really have to be monitored and how much of the total utility system should be considered in evaluating transmission use," notes EPRI's Iveson. "Incorporating new measures of transmission use into state-of-the-art control center computers for a continuous, on-line capability poses some interesting technical challenges."

With competition on the rise and greater pressure than ever on utilities' corporate balance sheets to maximize return on investment, transmission capacity is coming under greater scrutiny by utilities, regulators, and potential users alike. Answers to some key questions—how much transmission systems are being used and by whom, and how the operation of the systems can adapt to new economic and institutional realities—are closer at hand. ■

Further reading

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This article was written by Taylor Moore, with background information from Neal Balu, Robert Iveson, and Frank Young, Electrical Systems Division.

VICTORIA TSCHINKEL

Enthusiasm for the Environment

This former head of Florida's environmental regulation and present member of EPRI's Advisory Council is now an environmental consultant. Combining her knowledge with a knack for communication, Tschinkel does a lot of education and even a little advocacy.

Small talk about the Florida weather proved to be a good way to begin conversation with Victoria Tschinkel early this past summer. Several unusually rainy days in Tallahassee had caught her interest, and it was an easy transition from there to environmental matters, especially the Florida water resource problems that had dominated Tschinkel's 12 years with the Department of Environmental Regulation. She started as a field inspector in 1974, "tramping around dredge-and-fill projects for a year, making sure the wetlands were properly protected," and she left early in 1987 after seven years as the secretary of the department.

Now she's the technical specialist for Landers and Parsons, a firm of attorneys with a wide practice in environmental law. "It's an expertise that bears directly on our clients' needs," Tschinkel explains. "For example, I identify and recommend technical consultants, and I help make sure they answer the questions that need to be answered. Sometimes our clients don't know exactly what to ask, or how. I prepare witnesses for technical hearings and trials, too, and I mediate where matters of environmental science are at issue. I also facilitate a lot, helping clients communicate with government agencies or with public groups."

Thoughtful interest and conviction come across, whichever job is under discussion. They show up in Tschinkel's quick sense of the criteria that count in organizational management, her description of changing environmental management priorities, and her ideas on why we've become so intolerant of even very low health risks. They're apparent also in her observations on energy/environmental matters. Several organizations have caught and retained her advisory attention in the last several years, and she's been a member of EPRI's Advisory Council since 1986.

Most EPRI advisers are from electric utilities, where they work in technical specialties. Tschinkel and her Council colleagues come from constituencies outside the power industry, such as communications, conservation, education, finance, labor, manufacturing, medicine, merchandising, regulation, science, transportation, and welfare. The idea is for EPRI's planners and managers to gain firsthand impressions—individual or collective, split or consensus—of their utility R&D priorities from a wide and mixed body of U.S. society. Sometimes, as from Tschinkel, there also are impressions of EPRI's institutional and organizational character.

Growing up with enthusiasm

Tschinkel's eventually decisive career directions were in no way predicted by her early years, or by her university degree in zoology, or even by an early job as a biology lab instructor in Ithaca, New York, where Walter Tschinkel's postdoctoral work in entomology at Cornell took them shortly after their 1968 marriage.

Berkeley, California, was Tschinkel's home from the time she was three—when her father, physicist William Nierenberg, joined the University of California faculty—until she graduated from that school. In that time there were two years in Paris when Nierenberg was an assistant secretary general of NATO. "I was free to pick my school there," Tschinkel recalls, "and I chose Lycée Molière, which was challenging because I didn't speak French. But I wouldn't have done it any other way; it was a real French experience and it was wonderful."

Her subsequent high school and college years in Berkeley were also a real experience, but of a different kind. Civil rights activism came to the fore; Berkeley's free-speech movement became famous, or infamous, depending on your point of view; hippies flowered throughout the San Francisco area; and the Vietnam War created strong currents and countercurrents all across U.S. society. "Having a father on the faculty meant there were a lot of strong discussions in the family," Tschinkel remembers, "and there were differing feelings there, too, just as in the university community."

In 1965 her father left the Berkeley campus to became director of the university's Scripps Institution of Oceanography, a post he would hold for the next 21 years. (During that time, incidentally, he served two terms on EPRI's Advisory Council.) Now retired, Nierenberg is continuing to work on a biodiversity program for the National Science Foundation. He is convinced that loss of species—from worldwide deforestation and pollution—isn't getting the recognition it should, so he's championing the traditional biological sciences, pushing for cataloging and maintenance of the global biological community.

The scope and implications of that effort remind Tschinkel of something. "Enthusiasm. It's an important trait in my own life and work, and it's something I got from my father. He's continually enthusiastic about the task at hand, and he communicates it. It's difficult not to listen to him!" She speaks of her own maturation—learning more about the world, its good points and bad points, and realizing how many people don't succeed at what they try. "It's hard to hold enthusiasm; it's easy to let down. I appreciate how my father's enthusiasm hasn't diminished a bit. I find that remarkable. I value it. I'd like to keep mine, too."

Environmental regulation

Despite her earlier plan that zoology would lead to medical school, Tschinkel for a time lost interest in "a career with a big C." It was a matter of traditional thinking, she calls it, when she and Walter got their degrees. They didn't know how long he would be at Cornell in postdoctoral work, "so I just went with him and didn't think about a career at all. It wasn't until after we moved here, when he accepted a position at Florida State in 1970, that I gradually developed a strong interest in public service."

First came some three and a half years as a research station biologist and li-

"Historically, we've concentrated our efforts on individual, obvious sources of pollution—point sources. Now it's time to look at regional and global effects that often don't have point sources."

brarian. Tschinkel's curriculum vitae lists weekly sampling and gradual rejuvenation of freshwater ponds, planning and maintaining a library of 1500 books and 200 periodicals, editing and translating papers, and serving as curator of an earthworm collection.

She also moonlighted as a consultant on the environmental impacts of several proposed lake and pond developments, and this integration of research knowledge qualified her for a field assignment with the state agency that would soon become the Department of Environmental Regulation. Two years later Tschinkel became administrative assistant to the department secretary, and in 1977 she was named assistant secretary.

These positions were unique background for her 1981 appointment as DER secretary. "I understood the department," she says flatly. "I knew where to put my hands on everything, and I had many trusting relationships. I could focus full-time on the issues outside—getting legislative support and funding for DER programs. That's a real organizational need, but an outside appointee must take time to build a following, a constituency, before working on the issues."

Tschinkel methodically gave major attention each year to just one key issue; groundwater protection, wetlands, and underground storage tanks are three examples. But how she went about the goal wasn't automatic. "You know, my mother couldn't even kick me out of the house to sell Girl Scout cookies when I was a child. And I was always uncomfortable about the legislative process because of having to sell, but I knew it was important, so I did it."

What she did was mount educational campaigns and enlist support for DER goals. "That's what a leader is for," she says, "to get the outside world to come along to the way of thinking needed for an organization to get its job done." Tschinkel's key move was suggested by someone in a meeting with Florida's governor during her first year as secretary. "We need to meet with the newspapers."

As eventually reduced to practice, Tschinkel's two-year strategy was to elicit interest in a goal by introducing it in speeches for a year, then—beginning the autumn before a legislative session—meet with the editorial boards of major newspapers all over Florida. By that time specific bills would be taking shape, so her meetings usually included one or more state legislators who were championing the program.

Tschinkel is straightforward about her success. "It was very effective. The papers usually assigned reporters to follow the issue. Some articles would relate the proposed state legislation to local circumstances, and there would be editorials supporting our bill while the legislature was in session. People knew about the bill, and legislators realized they couldn't go home without dealing with it."

Achieving legislative goals, advancing Florida's environmmental management, and doing right by the DER staff were all part of the same cloth, in Tschinkel's view. And enthusiasm was part of it—"the positive feeling that things could happen, relaying that to the people who worked for me, convincing them that I knew how to make the system work.

"People need to be confident," she continues, "that their leader can produce what he or she should produce. The secretary's job looked more important than others, but I was also responsible for specific things. If I couldn't produce salary raises for DER employees, or safe equipment for them, or laws passed at the proper time, then I wouldn't be doing my part. That was my part of the bargain."

Non-point-source pollution

Florida would seem to be an ideal setting, a virtual laboratory, for water resource management practices. Watersheds are mostly within the state's boundaries, making independent jurisdiction possible; surface-water basins are flat and laced with swamps, ensuring all manner of interactions; soils are sandy and water tables are shallow, making for fast cause and effect. Today's surface drainage is tomorrow's well water; pollute it here, choke on it there.

The state is highly and variously developed, and it continues to feel strong forces of economic and population growth. Residential water use is extremely high, and it isn't all for air conditioning. "There's no native equivalent of a lawn here," says Tschinkel, "because the soil drains so quickly, but people plant them, and subtropical trees that take lots of water, too. People in south Florida may have wells, but it isn't real groundwater;

it comes from the lake-and-swamp system, and what you get every year is all you've got. There's only a certain amount of storage capacity in the system. And," she adds as the clincher, "90% of our population relies on such 'groundwater.'"

Tschinkel's twelve years in the microcosm of Florida's environmental regulation encourage her conviction that traditional pollution control management is nearing the limit of the results it can produce. "Historically, we've concentrated our efforts on individual, obvious sources of pollution—point sources. Now it's time to look at regional and global effects that often don't have point sources. Automobiles, for example. And storm water runoff is a major pollution source we've ignored—all the metals, all the greases, the turbidity."

The problem is one of lifestyle more than of intentional choice, Tschinkel believes. "We're getting into areas that are societal," as she puts it: "individual recycling of newpapers, bottles, and cans, buying things in fewer packages. But pollution control officers don't see that as their job; they're supposed to knock at the door of the pulp mill and order it to do better. None of us, layman or professional, is really trained in how to make these large societal changes.

"In fact," she concludes wryly, "we tend not to like people who tell us what we should do. But as a society we're maturing to a point where we must deal with societal issues. And one of them is non-point-source environmental pollution."

New family, new career

In 1986 Florida had a gubernatorial party change, and the Tschinkels started a family. Victoria Tschinkel resigned as DER secretary in February 1987, and Erika was born in March. Both events provoked thoughts about the when and where of working again.

Tschinkel's decision, not long delayed, was to resume professional work fairly soon after her daughter's birth, while she was still current. "But I didn't want to be working 18-hour days, or move the whole family for my career." She discussed these criteria with Landers and Parsons, proposing "that I cluster my work so as to be home one or two days a week while Erika is very young. And for the most part, I've been able to accomplish that."

For this and other reasons, Tschinkel finds Landers and Parsons an eminently suitable connection. She says the legal community in Tallahassee jokingly calls them a boutique law firm. "And we are! Environmental law isn't all we do, but it's about 85%, I would say. We're small, our clients for the most part are large, and they have a long-term orientation to Florida. They're attracted to us because they want to stay abreast of what's required—hopefully, ahead of it."

Communication is a large part of Tschinkel's work—ensuring that environmental reports communicate effectively, and helping individuals do so, too. "Sometimes a client has local trouble. People think they're polluting, or not meeting legal requirements. Just talking and showing numbers somehow isn't convincing. I sit down with people to find out what really concerns them, and how we can answer their questions."

Tschinkel's change of scene hasn't called for any change of viewpoint. "Probably," she says, "this is because I was the head of an agency and therefore continually called on to understand several different sides of a problem." But she has come to realize that the private sector functions much more like the public sector than the private sector had led her to believe while she was in government. "Our clients are very different from each other, just as different agencies and individuals are. The human factor is, after all, the overriding issue. What's that buzz phrase today? The corporate culture—how things are accomplished in a given firm. It varies so much from one to another. There's no such thing as how *the* corporation works!"

Tschinkel clearly finds the work as compatible with her needs as the hours. "I chose a group of people to work with who share my ethics and orientation." A tone of mission creeps into what she says. "I feel dedicated to our gaining greater respect for our surroundings. Really, that's been my career motivation. I feel a sense of mission in that, and I think it can be accomplished in different ways."

But isn't a law practice inherently adversarial? Not to Tschinkel. For example, there's no presumption that environmental regulation is against the interests of Landers and Parsons clients. "If new

"I think EPRI needs to be prepared to push *its members toward the next generation of technology, and not to rely on revisions that will very quickly be obsolete."*

legislation has merit, if it's well thought out and can be implemented fairly, we support it," Tschinkel says. "We sit down with public agencies to learn their upcoming priority issues, and we position ourselves to be supportive if we possibly can.

"How to put it? We do some lobbying; we also advise our clients what is in their long-term interests. But no," she concludes, "here, in Florida, working as we do, I don't believe we're seen to be in an adversarial role."

Energy/environmental advice

There's an inquisitive side to people who become organizational advisers. The opportunity is first of all one of learning, in order to advise. And once taken, where does it end? Tschinkel said yes to EPRI in 1986 partly because she had said yes to the Office of Science and Technology back in 1978.

That early occasion was a working group review of research sponsored by the Department of Energy. A year later Tschinkel became a charter member of DOE's Energy Research Advisory Board, an energy/environmental position she held until 1986. The Advisory Council of the Gas Research Institute followed in 1983, appealing to her interest in both organizational and technical matters. And since 1986, the year of her EPRI appointment, Tschinkel has been a member (currently she is chairman) of the Solar Energy Research Institute Advisory Board.

Of her EPRI service she says, "It isn't just the technical questions of generating power cleanly and inexpensively, but also how to accomplish that when you have such a strong pattern of government/industry/regulatory relationships. That interaction is unique." It also strikes her as effective; it's marked by EPRI's staff being encouraged to think ahead about what the next industry technical issues are likely to be, as well as to develop solutions for today's problems. "Along with that, I've been impressed by EPRI's independence from the people it serves—which I think serves those people best."

There's another side to that connection, though. Tschinkel senses that, because EPRI is designed to be intellectually independent (so as to be objective and thus credible), it also has the inherent weakness—"or perhaps I should say necessary evil"—of difficulty in gaining the day-to-day attention and respect of a lot of middle-management utility people. "It's difficult to put a finger on," Tschinkel admits, "but in Florida I've known some men and women who don't easily see the relevance that EPRI has for them and how they do their work."

This matter is clearly part of the larger subject of technology transfer. But it isn't the technical content; it's what Tschinkel calls technical public relations, or industry relations, and she concludes that "it's probably the toughest part of EPRI's job because of the organizational and institutional relationships."

There are also hot issues in the technology spectrum. As an environmental manager (or consultant), Tschinkel quickly mentions three. One is clean coal technologies for power generation. She foresees that new Clean Air Act proposals—even without the enactment of legislation—will put many utilities under pressure to make some rapid decisions.

"They're going to need some very competent independent advice when they face all the interim and make-do options that will be offered," Tschinkel says emphatically. "I think EPRI needs to be prepared to push its members toward the next generation of technology, and not to rely on revisions that will very quickly be obsolete." Speaking directly, she adds, "You know a lot in this area. You need to gear up in anticipation, to work out internally how it needs to be done—how it *would* be done—before any act passes."

Another important, somewhat related technology area today is that of power plant upgrading—repowering, replacing, or rebuilding within the walls and fences of today's sites. It sounds mundane, she admits, but she adds the rueful observation that "because of the not-in-my-backyard problem, Americans aren't going to want new things built anywhere."

Tschinkel's third hot topic today, and the one with highest visibility, is EMF, the electric and magnetic field phenomena associated with overhead power lines. She remembers talking with EPRI President Dick Balzhiser about EMF when

"Our society is so preoccupied with risk. I'm not talking about sensible concern with general safety. I mean preoccupied, obsessively, with very low risk."

Florida was just beginning to work on regulations. "I encouraged EPRI's expanded EMF program," she recalls, adding, "I think it sometimes helps to be outside an industry, so as to see an issue. EMF is definitely one that's here to stay. It is so difficult."

Tschinkel hesitates. "I have a very strong thought about this. It goes beyond EMF alone; it's about the psychology involved. Our society is so preoccupied with risk." She quickly amplifies the point, saying, "I'm not talking about sensible concern with general safety. I mean being preoccupied, obsessively, with *very low risk.*"

"I don't think individuals see their responsibilities as clearly [as private industry does]. We still fertilize our lawns, pour paint down the drain—those kinds of things. . . . I mean, how many of us go into a fast food chain and say, 'Just put my burger on a paper napkin, please'?"

Living in a high-tech world

No easy resolution follows Tschinkel's opinion, but she offers some conjecture as to the forces at work. "I think we're fundamentally not happy with the lifestyles we 'enjoy' in our highly technical society. Even though we have 'chosen' the paths we're on, we feel very pressured and rushed much of the time.

"Then," she goes on, "you know how you focus your discomfort, your anger, on something else, something you feel forced to endure?" In Tschinkel's tentative view, our chosen scapegoats often are minor threats compared to our unspoken anguish over working too hard or not having enough discretionary time with our families, much less for ourselves. "From my environmental work," Tschinkel concludes, "I have the impression that we misdirect a lot of anger against those who might somehow affect our health."

Seen in this way, perceived environmental risks to human health are inappropriately influenced by our unrest over societal values that we haven't questioned, personal choices that we haven't been aware of, and phenomena we don't fully understand.

Despite Tschinkel's bleak view of our undue concern with health risks today, she is generally optimistic that society will get it together. Coming to grips with non-point-source pollution is an example, evidence, as Tschinkel puts it, "of growing recognition that we're all part of a very complex biological organism. Furthermore, I would say private industry has understood this longer than most individuals."

She points out that industry is increasingly responsible; corporate executives know that in order to continue operating their large investments, they must learn to function in physical and social harmony with the community. Environmental laws and accounting laws, together, are clear and persuasive.

"I don't think individuals see their responsibilities as clearly," Tschinkel says. "We still fertilize our lawns, pour paint down the drain—those kinds of things. We don't assume enough responsibility as buyers to favor the marketers who are socially responsible. We have a lot of power. We haven't used it. Yet. I mean, how many of us go into a fast food chain and say, 'Just put my burger on a paper napkin, please'?"

But Tschinkel believes the next great wave will be citizen driven. "Citizens will be the enforcers. Government will still go after point sources, orchestrate more comprehensive storm water management. But in the end, it's not going to be socially acceptable to overwater your lawn or dump extra fertilizer on it."

The pace of environmental progress remains uneven. "I think we've made a big mistake by not having a major tax on gasoline products," Tschinkel remarks, "except maybe home heating oil. In the long run, it's no environmental favor to have cheap gasoline and large cars." But she observes that the same legislative process has consistently favored wilderness land acquisition.

"I think that's a hopeful sign. It's very strong here in Florida, I know. Floridians will tax themselves for very few things, but land for low-impact wilderness parks is one of them. Congress continues to set aside Forest Service lands, too. So even if we aren't all doing everything for the environment that we should in our daily lives, we're saving it with our tax dollars. Next, we'll save it with our own actions." ■

This article was written by Ralph Whitaker and is based on an interview with Victoria Tschinkel.


New Yorker

SHINING PROMISE FOR INFRARED PAINT CURING

Precisely timed and computer-controlled, infrared heat is a new wrinkle in the paint shop of a pioneering Chrysler assembly plant. An unmatched, mirrorlike finish and better control of volatile solvent emissions are the payoffs of this advanced electrotechnology application.

Color and luster have been automobile sales features ever since the days when Henry Ford is supposed to have said, "You can have any color you want, so long as it's black." Other early manufacturers didn't follow this austere dictum, and bright colors soon began to appear on sport and country models. Paint durability also became important as cars began to last longer—and to spend more time outside the garage.

By the 1930s, U.S. motorists were no longer tinkerers and adventurers. The call of the open road had come to have mass appeal, and we were a mass market, buying in on peppy performance, a solid-sounding door slam, or a reputation for colorful and shiny paint that stayed that way.

Ford's sporty V-8s built their following on just such points, in part, perhaps, because of the company's pioneering work with infrared heat for curing auto body finishes. For the most part, however, IR process heat was premature in those days; there wasn't adequate control of its time and intensity. Black-wall IR ovens (using gas heat behind their walls) found a place, but electric IR continued to falter during the 1940s and even the 1950s.

Today, though, state-of-the-art electronic control is putting infrared energy into the big time as a U.S. electrotechnology. Electric IR is being used to dry the basecoat paint on two luxury-model automobiles, the Chrysler New Yorker and the Dodge Dynasty, built at Belvidere, Illinois. In an effort called Project 19, Chrysler has introduced new coating formulations and a new electric IR forced-flash process. The results—beginning with the 1988 models—have been the highest marks recorded anywhere with a new instrument that measures smoothness by the quality of a reflected image.

Project 19 was initiated by Roy T. Smith, director of paint and pilot operations at Chrysler's Outer Drive Manufacturing Technical Center in Detroit. The project takes its name from the goal it achieved: readings of 19 on a scale of 20, the smoothness of polished black glass. Chrysler's people say the New Yorker and the Dynasty exhibit the best appearance they've produced in 63 years; they flatly claim "the finest paint finish on any car in the world."

That's the direct and obvious production benefit, but electric IR also is easing Chrysler's problem with the volatile organic compounds (VOCs) that "flash off" from solvent-based paints and must be captured. Conventional automotive paint ovens dry and cure finishes mostly by convection, and they use huge volumes of gas-fired hot air for the purpose. Electric IR, however, requires no special airflow, because the energy radiates directly to the painted substrate, without heating the intervening air. Thus, the VOCs from Belvidere's new IR oven are easily managed today—and they should be sharply reduced when Chrysler switches from solvent- to water-based coatings.

This neatly packaged success story results from a collaborative effort that teamed the automaker with its paint supplier, PPG Industries, and the IR system developer, BGK Finishing Systems. The new development was encouraged by Commonwealth Edison, which supplied a pair of higher-capacity transformers, and by EPRI's Center for Materials Fabrication (CMF), which provided technical support. Lee Semiatin, the project manager for the CMF, says, "Chrysler's success is real. We've collected data for technology transfer to EPRI members and their industrial customers. And we're planning several more projects to develop IR systems for product and environmental quality improvement."

Time, temperature, sags, and pops

Greg Bartos, who supervises Chrysler's paint shop operations at Belvidere, describes the impetus for development of the new finish. "Pigmented basecoats and transparent clearcoats have been around for years, and auto industry practice pretty much has been to apply them 'wet on wet,' one right after the other, and then send the car body into an oven to dry and cure. Fast-evaporating solvents begin to flash off from the basecoat right away, though, even while it's still being applied. This helps prevent paint 'sag' on vertical surfaces, and it also results in a stronger foundation for the clearcoat."

The wet-on-wet approach means just that, according to Bartos, and Chrysler's former practice at Belvidere allowed only about 4 minutes for basecoat flash-off in the ambient air of the spray booth. Then clearcoat application began. Because of temperature differences between thick and thin metal sections, however, flash-off results weren't uniform. Some solvent remained in the wet basecoat, and there would be frequent "solvent pops"—Bartos's term for delayed releases of solvent, which bubbled through the clearcoat film after it had begun to set and could not flow closed again quite so readily. Surface smoothness suffered accordingly.

Chrysler's three-year project to test and introduce a new finish began with the concept of a high-gloss effect. This was the major feature of a basecoat-and-clearcoat system proposed by PPG Industries. The basecoat was a high-flow (slow-curing) formulation that would be applied more thickly, under precise control, for better "hiding" capability—that is, better filling and smoothing of metal substrate irregularities. The clearcoat was planned for a thickness of as much as 2.4 mils, some 25% greater than customary.

The clearcoat is what gives an automotive finish its gloss. It has a magnifying effect, too, and increasing its thickness enhances whatever surface character is beneath it. As an added appeal, PPG's new clearcoat formulation is free of isocyanates and therefore poses less of a health and emissions control problem for Chrysler.

All in all, the new basecoat-clearcoat combination was seen to be a winner. Still, success hinged on innovations in process technology. One was a precise and reliable means of applying the new clearcoat, which is formulated from two components that must be combined at the spray nozzle, in the manner of some foams and adhesives.

Another innovation was a way to flash off the slow-curing basecoat solvents quickly and uniformly enough to make a firm foundation for the extrathick clearcoat. Chrysler's solution, developed cooperatively with PPG Industries and BGK Finishing Systems, was to place a compact and highly controllable electric IR oven right in the spray booth, between the basecoat and clearcoat paint stations.

High-intensity, shortwave IR radiation, emitted at up to 4000°F from tungsten filaments in gas-filled quartz tubes, produces a fast, "forced" flash-off of the solvents in the high-flow basecoat and essentially sets its smooth surface. The clearcoat application follows immediately, in a sequence that Bartos describes as wet on tacky. "The basecoat is strong enough to support our thicker clearcoat, but the two layers really cure together

Electric Infrared on the Assembly Line

The computer operator keys in the basecoat color and car body codes, thereby controlling the paint spray equipment and programming the timing and intensity of electric IR drying cycles.

Painters spray interiors, under hoods, in wheel wells; then foil-clad robotic equipment takes over—30,000-rpm rotary spray "bells" and reciprocating spray guns that apply a film of finely atomized paint up to a thickness of 1.8 mils.

The electric IR oven, located right in the spray booth itself, is the centerpiece of Chrysler's new paint shop. Radiant heat works from the inside out, driving off volatile paint solvents in less than 30 seconds and making a firm base for the 2.4-mil clearcoat that comes next.

when they leave the spray booth and go into the final oven for half an hour."

Fast, uniform, smooth, and shiny

The IR exposure is just under a minute for a car body moving at 13.5 feet per minute on the paint line conveyor. That short interval is matched by the IR oven's abbreviated length—only 16 feet, barely long enough for the back end of a New Yorker to go in before the front end comes out. Neither dimension suggests how the oven exposes each car body to a 40-step "wave" of IR energy that is custom-tailored to the car's length, color, profile, and metal thickness.

Lengthwise, the oven is divided into five 3-foot zones that contain 34 IR emitters each—14 per side and 6 across the top. Only two of the zones are programmed to flash off Chrysler's solvent-based basecoats today; all five zones will come into play when water-based paints are introduced, probably during the 1990 model year.

The oven has full-range IR capability; that is, emitter power levels can be adjusted to vary the IR wavelength through both the medium range (2.3–3.3 micrometers) and the high-intensity range (0.8–2.2 micrometers). A computer steps all the emitters through their cycles, according to the body color dialed in by the spray booth operator.

There is a computer program for each of three families of basecoat color: white and light-colored metallics, dark metallics, and black. Each program deals with three key variables—the basecoat film thickness, the metal substrate thickness, and the distance from the emitter to the car body.

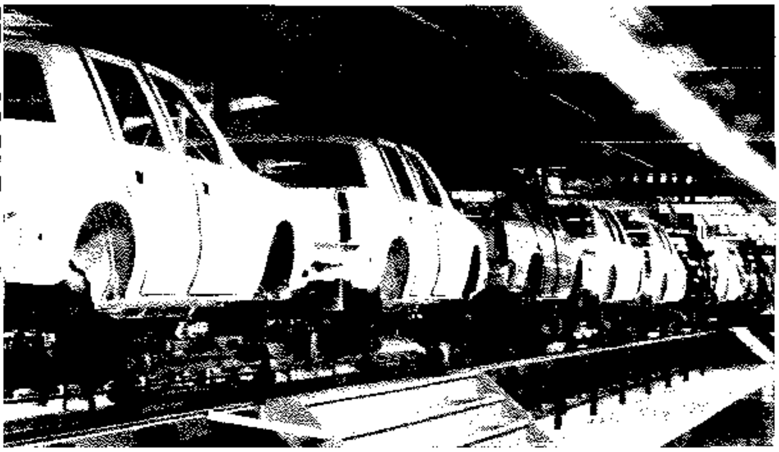
Film thickness (known as film build) is a function of color. Surprisingly, perhaps, fully covering the primer requires a greater film thickness of colored paint (1.6–1.8 mils for some pastels) than of metallic (only 0.6 mil). Also, drying a heat-absorbent color calls for more IR energy than does, say, a metallic silver. This seeming contradiction is a reminder that the paint itself is largely transparent to the IR energy. Rather, the IR energy directly heats the underlying metal, and conduction then dries the paint by driving off the volatile solvents.

This phenomenon is one of the unique attributes of IR energy. Because the basecoat dries from the inside out and its surface is the last to dry, solvent pops are a thing of the past.

While there is a calculable quantum of IR input that is just right for a given basecoat color and film thickness, the changing substrate thickness must be taken into account. This is also done by programmed variations of the electric IR intensity. Individual emitters adjust in milliseconds according to the calculated heat dissipation behavior of the different metal sections passing by in quick succession. In the same manner, IR emitters across the top of each oven zone respond to the profile of the car body's upper surfaces (low hood, high roof, low rear deck) as they pass underneath.

Such precisely timed IR control is key to ensuring that basecoats don't get beyond

Smoothness is captured on film—the photographic image of a finely graduated pattern reflected by the mirrorlike finish on a car door. Polished black glass may register 20; Chrysler achieves 19.



Chrysler is making its first use of electric IR heat on the basecoats and clearcoats of its luxury models. Primer-coat cures and final oven cures of complete finishes are likely further uses of infrared processing.

180°F, regardless of metal thickness. Temperatures higher than that will initiate cross-linking, an essential step in curing some finishes, before the clearcoat is in place.

The value of this forced-flash approach carries over in several ways to the clearcoat. Most of all, it ensures a strong foundation for a thicker clearcoat than heretofore. Though essentially dry, the basecoat is still tacky enough for good intercoat adhesion when the clearcoat is applied. And there's no more soaking in of the clearcoat. Also known as tailing, this intermingling of basecoat and clearcoat at a conventional wet-on-wet interface slightly clouds the clearcoat. It would detract from the visual qualities of luster and richness, which are otherwise magnified by the 25% greater depth of clearcoat on autos from Chrysler's Belvidere plant.

Altogether, then, it's the precision of electric IR heating—of intensity, timing, and direction—that makes possible the paint system and spray booth sequence introduced at Belvidere two years ago. Electric IR gives greater freedom to the people who formulate the materials and also those who design the application processes. Their rewards are measurable improvements in both finish smoothness and paint shop emissions control.

High gloss, low emissions

Instruments tell the story of Chrysler's Project 19 finishes. The key quality is distinctness of reflected image, abbreviated DOI, and Chrysler especially points to the results measured with the Tension meter, an instrument developed in France that produces a photographic record. The Tension standard is a grid pattern of progressively finer lines (numbered from 1 to 20) that is projected on the painted surface, reflected by it, and photographed by a Polaroid camera. Polished black glass is one of the few surfaces that reflect a discernible image of the finest (number 20) Tension grid.

Advance research on individual cars made by various companies turned up

The Bright Spots of Infrared Technology

There are several features of electric IR energy that have opened up new possibilities for Chrysler in formulating, applying, and drying automotive finishes:

Precision Tightly controlled by computers, IR energy emitters can be repetitively and reproducibly switched on and off (or their intensities adjusted) within millisecond intervals, allowing precise aim, precise temperature levels, and precise timing.

Speed The specificity of electric IR permits custom timing and intensity for each application in sequence, resulting in a tighter schedule for the entire process. At Chrysler's Belvidere plant, IR does a former 4-minute job in less than 30 seconds.

Space The short, compact electric IR oven fits right into the 20-foot-wide spray booth, adding nothing to the overall paint shop space requirement.

Cleanliness Timed and targeted electric IR permits the use of paints with a lower solvent content, which yield a lesser amount of volatile organic compounds to be removed. Also, radiant energy transmission involves no air movement and reduces the overall volume of exhaust flow.

Flexibility Because electric IR can be exactly measured and timed, there is more latitude in paint composition, viscosity, solvent type and content, curing characteristics, and so on.

Efficiency Electric IR heat does its job in less time, in less space, with less air, and in exactly metered doses, with less waste heat.

Shine Electric IR results in a smooth, high-gloss finish for the sales appeal that makes it all worthwhile.

just a few 19s here and there—hence Chrysler's name and goal for its new paint line. Today, black finishes and white finishes score best at Belvidere: consistent 19s on horizontal surfaces, 16s and 17s on vertical surfaces. For the metallic colors also used on New Yorkers and Dynastys, the analogous values are 18 and 14. (In comparison, the best Tension readings on metallic finishes before Project 19 were 16 on horizontal surfaces and 10 on vertical.)

DOI instrumentation responds to the reflective fidelity of the so-called first surface, the virtually molecular and (hopefully) glasslike region at the very top of an automotive finish. There are a number of DOI instruments, each employing a defined light source intensity, angle of projection (incidence), sensor (and position), and scale of values. The Hunter goniophotometer, for example, electronically quantifies the reflected light received by photosensitive detectors at the exact angle of reflection. It registers DOI values of 94–97% for black finishes rolling off the Belvidere line today, well above the 85–86% range measured before Project 19.

Airborne VOC emissions are another problem being corrected by the use of electric IR drying in Chrysler's Belvidere paint operation. With EPA compliance requiring progressively tighter controls in recent years, automakers now have little maneuvering room between the technology costs of improving ambient air quality and those of improving automotive finishes. One measure of the problem is that the volatile organics (that is, the solvent itself) in a single gallon of typical basecoat paint today may weigh more than 12.25 pounds.

Electric IR drying is enabling appreciable changes. For one thing, Chrysler's new basecoat has a lower solvent content to begin with. It is thus slow to evaporate, a property that enhances paint flow-out and eventual smoothness but one that would not be feasible without the fast, forced flash of electric IR.

Also, the new IR oven doesn't add new air requirements. In fact, as positioned in the spray booth, it localizes the origin and reduces the volume of VOC emissions to be dealt with.

The spray booth is a clean room, with a steady downdraft of filtered air to control dust and to protect workers by collecting paint droplets, both those from manual and robotic spray guns and those that escape the electrostatic attraction set up between the positively charged paints and the grounded car bodies. In a new twist, the electric IR oven itself has induced-draft fans. These collect VOC-laden air from that enclosure and pipe it away to join exhaust from the forced-air, convection-heated final curing oven. The combined exhaust stream is then directed to a gas-fired combustor, where the VOCs are incinerated at temperatures of 1400°F and higher.

Powders, primers, and productivity

With electric IR technology affording such latitude in the control of solvent-based finishes, Chrysler looks forward to still greater freedom in paint formulation, mainly to the use of water-based paints with much-reduced VOCs and powder paints with none at all. Neither paint type is assured to be applicable for every kind of coating, but primers, gravel-resistant lower-body treatments, basecoats, and clearcoats are all under consideration. And any of these applications would represent a big step in terms of compliance with air quality standards.

Water-based paints are a specific goal of Project 19, and that's why the electric IR ovens in the Belvidere spray booths have three more zones of emitters. The full oven is expected to flash off 95% of the basecoat moisture in less than two minutes.

Powder paints are just that—fine particles of pigment, electrostatically sprayed on auto surfaces and IR heat-fused to flow out smoothly, then cooled to harden in place.

Electric IR technology is showing up at other points in the paint line sequence. For example, in an application under study by the CMF, Chrysler's Outer Drive R&D facility is using an electric IR oven to cure "E-coats"—the term for electrostatically applied primers on auto bodies. As at Belvidere, the aim is to complete the coatings faster and with closer control of temperature.

According to Chuck Bergman, executive vice president of BGK Finishing Systems, the 350°F preheat temperature necessary for an E-coat can be attained in 2 minutes with electric IR, as opposed to 8–10 minutes with gas-fired black-wall IR ovens. Furthermore, electric IR precision means that the temperature gradient between light and heavy metal sections can be held to as little as 20°, compared with 50° or more.

Another early future step should be the substitution of electric IR for black-wall IR in final curing ovens. Again, the new technology will save time (perhaps 6 minutes out of what is now a 30-minute procedure) and improve precision in reaching and holding the required temperature (325°F).

But back to today's reality at Belvidere, Illinois. Electric IR there is a many-faceted factor of productivity. It's a timesaver—27 seconds versus 4 minutes for flashing off basecoat solvent. It's also a precise controller of temperature, enabling solvent concentration to be reduced. In turn, this cuts the volume of airborne emissions to be handled and incinerated.

And it's all done with a dialable power density of 50 to 100 watts per square inch of painted surface, and at an estimated energy cost of only 8 cents per car. The result is a high-gloss, "wet look" finish that for the time being is unique in the U.S. auto market. ■

This article was written by Ralph Whitaker. Technical background information was provided by Robert Jeffress, Customer Systems Division.

TECH TRANSFER NEWS

An EMF Monitor You Can Wear Like a Walkman™

The measurement of individual exposure to electric and magnetic fields (EMF) in the course of daily life is now possible, and a handy instrument for the purpose is available. EMDEX—for electric and magnetic field digital exposure—is a combination of detection and memory microcircuitry and PC software to analyze and display EMF exposure data.

Measuring 6 by 4 by 1.5 inches and weighing about a pound, the EMDEX unit is worn in a belt pouch, and the duration of its stored record can be as long as a week, depending on the preprogrammed EMF sampling rate (once per second is the maximum). Programming options and accessories adapt the equipment for monitoring exposure to electric and/or magnetic fields. The output program provides a choice of graphic displays—such as time plots and histograms—for quick and easy data interpretation.

The mechanisms and degree of human health hazard from EMF exposure are still uncertain. Answers must come, over time, through extensive epidemiological and biological research, as well as through characterization of our exposure to a tremendous array of recognized EMF sources, from microwave ovens and TVs to power and broadcast communication facilities, computers and word processors, laboratory electrical and electronic apparatus, and industrial motors and high-current furnaces.

In the meantime, the highly portable EMDEX system should be useful in utility studies of EMF exposure. Combined with a diary or log of activities and whereabouts, it's a way to accurately answer questions such as "How much EMF exposure is the individual getting? Where? How often does exposure occur? How long does it last?" Developed for EPRI's environmental research in health factors, the new monitor turns up unexpected answers and sources: a worker's exposure to the field surrounding the structural steel concealed in an office wall; a schoolchild's exposure when she sits beside the classroom movie projector.

As part of the EMDEX technology transfer effort, EPRI and 55 utilities are now cooperating in a joint project to compile a database of occupational EMF exposure. For information on the EMDEX system, contact the EPRI-licensed manufacturer, Electric Field Measurement Co., in West Stockbridge, Massachusetts, (413) 637-1929. ■ *EPRI Contact: Stan Sussman, (415) 855-2581*

Global Goal for Technology Transfer

The world is ready for greatly increased electrification in the developing nations, and the international power community is well positioned to take the initiative. These perceptions were voiced last May by Hiroshi Narita, president of the Central Research Institute of the Electric Power Industry (CRIEPI), the counterpart of EPRI in Japan.

Speaking at the conclusion of a three-day meeting of EPRI and CRIEPI executive and technical management in California, Narita envisioned an eventual "electric civilization," saying that it must begin with cooperation among the research institutes of the developed nations. "Furthermore," he added, "to ensure smooth transfer of technologies to the developing nations, it is important to promote mutual understanding and cooperation of the nations on a global scale."

EPRI and CRIEPI have been linked by research agreements for well over 10 years. Joint meetings are held every 18 months, alternating between Japan and the United States, to review R&D progress and prospects. This year, for example, cooperation was established to support further research on the human health aspects of electromagnetic fields and the impacts of global climate change.

Specialized technical sessions at the EPRI–CRIEPI meetings are conducted through interpreters, but Narita's speech to the entire group was simultaneously translated, speeding his communication and symbolizing both the challenges and the opportunities of a worldwide electric civilization.

Narita based his vision on the imperatives of environmental protection and humankind's fulfillment—"to live with hope." He said that advanced institutions and nations should therefore take global responsibility for the wise use of energy—that is, reliance on the sources that have the least environmental impact and development of the highest energy efficiency from all sources.

Transactions, meetings, and exchanges under EPRI's various R&D agreements are coordinated by the manager of international activities. ■ *EPRI Contact: Jay Kopelman, (415) 855-2836*

Chemical Data Compiled for Organic Compounds

Protecting soil and groundwater from contamination by hazardous and toxic wastes, fossil plant solids, and other solubles is a major concern to utilities. Until recently, however, data on the environmental behavior of most organic compounds were inadequate, or at best, difficult to locate.

Chemical Data for Predicting the Fate of Organic Compounds in Water (EA-5818) is a two-volume guide to published information on the physical properties and chemical and biochemical transformation characteristics of 53 organic compounds. The data represent the results of a search of some 340 references published before January 1988. Data gaps are identified.

In compiling the book, EPRI-sponsored researchers systematically selected data on physical properties, chemical degradation rates, speciation constants, and biotransformation rates, and they supplied estimated values for some cases where data were not available. Volume 1 presents the technical basis used to develop the reference guide and tells how utilities can use the data. Volume 2 presents the data and includes an index of information sources for each chemical.

The database can help utilities assess the potential impact of organic compounds on land and water quality and the effectiveness of different methods for cleaning up organic compound contamination of soil and water. ■ *EPRI Contact: Ishwar Murarka, (415) 855-2150*

Everything You Always Wanted to Know About EVs

What's the difference in emissions for an electric vehicle and a gasoline-powered car?" The semi-trick question came from a caller at an East Coast utility. The straightforward answer came from EPRI's ETIC—the Electric Transportation Information Center.

ETIC found its answer in university research sponsored by a California utility—a comparison based on exhaust-measurement data for conventional cars and on the power plant mix and hence the emissions traceable to the electricity necessary to "fuel" the same annual mileage in the utility's service territory.

This example illustrates some highly specialized technology transfer and the novel means for doing it. ETIC is a dedicated library and computerized database, combined with a nationwide phone number—a call-in service that is free to EPRI members and available at $80 an hour to designated "affiliates."

The major focus is electric vehicles, but ETIC's charter extends throughout electric transportation—to mass transit, people movers, light rail, electrified roadways, and battery systems. The center has been in operation for just over a year, collecting, storing, and disseminating data. Because answers are stored for easy retrieval, there are fewer and fewer hard questions, according to ETIC coordinator Cynthia Veneziano. Most inquiries, however, are still one of a kind, she says.

ETIC's data are organized in six categories: technical facts, utility activity, publications, market information, environmental and utility impacts, and statistics. Service is limited to information searches, mostly of print sources. But the center has access to a variety of experts in electric transportation—at universities, at DOE, in consulting firms, at EPRI, and in the offices of manufacturers. Where necessary, ETIC consults those experts directly, or even puts them in touch with questioners. The ETIC staff answers calls at 1-800-848-3842 five days a week from 9 a.m. to 5 p.m., Pacific time; a recorder takes message queries after hours. ■ *EPRI Contact: Bob Swaroop, (415) 855-1097*

Preview 15 Research Videos With a Single Cassette

Utility professionals who want to learn what EPRI research projects are portrayed on videotape can do so, right at their TV sets, with the Institute's "research samplers," cassettes that present a series of one-minute introductions edited from longer research videos. The samplers preview most of the more than 120 EPRI research videos now available.

Samplers 6–8 are the newest releases. Titles range from "The Greenhouse Effect: To What Degree?" to "Electric and Magnetic Fields and Human Health." Other titles address clean coal technologies, gas turbine expert systems, PCB risk assessment, the EPRI lightning detection network, robots and robotics, and photovoltaic electricity research.

Employee orientations, management meetings, media briefings, service club programs, technical department meetings, and professional society meetings are typical occasions when utilities need audiovisual coverage of selected research programs and findings. Since EPRI's full-length cassettes cover such a variety of research, the samplers serve as a visual catalog for quickly learning the subject, level of detail, and intended audience. Also, titles alone don't always pinpoint the topic being presented. "We try to be both clear and precise in naming the videos," says Dennis Clinthorne, EPRI's video manager, "but this isn't always possible with very technical subjects."

Each sampler contains 15 one-minute previews. A new one is issued every seven or eight months. A listing of titles on samplers 1–8 is available. ■ *EPRI Contact: Dennis Clinthorne, (415) 855-2271*

Advanced Fossil Power Plants

Fuel Cells

by Edward Gillis, Generation and Storage Division

In its efforts to make fuel cell technology available to member utilities, EPRI's Fuel Cells Program has two major goals:

- For the near term, the goal is to provide small, modular dispersed generators featuring heat rates of 6000–8000 Btu/kWh; emission, noise, and aesthetic characteristics that will allow the power plants to be sited in urban areas; and installed-cost targets for 10-MW-class units of $1200/kW at the time of market entry and $800/kW in mature production (1989 dollars).
- For the long term (after the turn of the century), the goal is to provide modular central station plants that, when integrated with coal gasifiers, will produce electricity with the highest efficiency and lowest emissions of any coal-fueled plant known. These plants are projected to have a heat rate of 6800 Btu/kWh and total airborne emissions (i.e., NO_x, SO_x, hydrocarbons, and particulates) of less than 0.05 lb/MWh; the installed-cost target for the plant is $1200–$1500/kW, depending on the type of gasifier and gas cleanup system required.

The rate of technical progress toward meeting these goals has been rapidly increasing. This acceleration is due in no small measure to technical programs being instituted in Japan and Europe. The Japanese interest in fuel cells seems to be driven by national goals to minimize fuel imports (thus the interest in high efficiency) and to site relatively small generation units in urban areas (as an alternative to transmission and distribution system upgrading)—as well as by an interest in exporting factory-assembled modular units. The Japanese utilities view fuel cells as the most efficient user of their expensive imported liquefied natural gas (LNG) in the near term and as a promising candidate for clean coal-fueled central station plants in the longer term.

In Europe the interest in fuel cells seems to be driven more strongly by environmental concerns than it is in the United States or Japan. Natural gas is becoming available in larger quantities and at more locations than ever before, and the "green" political parties are advocating its increased use—as opposed to coal, oil, or nuclear capacity—to mitigate deforestation, deterioration of monuments, and other effects attributed to air pollution. The use of fuel cells in relatively small CHP (combined heat and power) units would provide the most efficient and cleanest energy service from the European natural gas resources.

ABSTRACT *EPRI has sponsored a broad range of projects aimed at developing fuel cells for use by electric utilities. Demonstrations of fuel cells for dispersed-generation applications using much of this technology are under way in Japan and Europe. For the benefit of its member utilities considering dispersed generation for capacity additions or shaping electricity supply, EPRI is collaborating with the foreign utilities involved in these power plant demonstrations in order to obtain early results at minimum cost.*

International activity

The Japanese and European activities bear on the future availability of fuel cells in the United States in important ways. First, collaborative R&D between U.S., Japanese, and European manufacturers is increasing. Bringing some of the international resources together cooperatively rather than competitively is a key reason for the increasing rate of technical progress. Second, Japanese and European utilities will probably be the earliest users of fuel cells. Hence most of the high costs of the initial demonstration and market entry power plants will not fall on U.S. utilities or consumers. Moreover, the products introduced to the U.S. market should have benefited from the overseas operating experience and thus be higher-reliability, better-quality products.

Utility demonstrations of first-generation, phosphoric acid fuel cells are under way in Japan and Europe. Tokyo Electric Power Co. (TEPCO) is constructing an 11-MW commercial prototype power plant at its Goi thermal power station site on Tokyo Bay (Figure 1). AEM, the municipal utility of Milan, Italy, is constructing a 1-MW pilot plant as part of a new industrial park being built in its service territory. Both of these plants will undergo precommissioning checkout in 1990 and will begin power generation tests in 1991. EPRI has information exchange agreements with both TEPCO and AEM that specifically address these projects. Consequently, power plant performance, operability, and reliability data will be available promptly to interested EPRI members. Under the terms of the agreement with TEPCO, member utilities can also visit the Goi site to observe plant operations during three specific periods of the demonstration. The first of these site visits is planned for March 1990, when EPRI members will be able to inspect the plant closely and participate in some of the operator and maintenance personnel training activities.

International Fuel Cells of South Windsor, Connecticut, will manufacture the fuel cell stacks and provide other equipment and services for both of these phosphoric acid fuel cell plants. In addition, the plant in Milan will use a fuel-processing system developed by Haldor-Topsoe of Bayport, Texas. Since EPRI has sponsored much of the R&D on which the equipment from these two manufacturers is based, the demonstrations will serve to evaluate EPRI-developed technology.

Recent progress

Much progress has also been made recently in second-generation, molten carbonate fuel cells (MCFC). Energy Research Corp. (ERC) of Danbury, Connecticut, is EPRI's principal MCFC developer. Over the past 18 months, ERC has successfully demonstrated scale-up of molten carbonate cells to a practical size (i.e., 4 ft^2, which generates about 400 W/cell) and will assemble a large number of cells (60 cells in the initial test) into a single high-voltage module. Three short stacks of the large-area cells, containing up to 11 cells each, were assembled, and their performance exceeded targets by about 5%. Two of the stacks were able to consume natural gas fuel directly, in addition to gas mixtures that simulate the products from coal gasifiers. EPRI is sponsoring endurance testing of one of the stacks. To date 4000 hours have been logged, including three shutdowns to ambient temperature and numerous short shutdowns simulating daily cycling. Cell performance degradation results have been better than the target of 0.4% voltage loss per 1000 hours of operation.

Other sponsors of R&D at ERC include Pacific Gas and Electric (PG&E) and the U.S. Department of Energy (DOE). The activities are closely coordinated. For example, EPRI and PG&E will equally cosponsor construction and testing of a 60-cell, 4-ft^2 module (20–25 kW) at ERC in 1989, an effort that will serve to verify the design and manufacturing process for larger stacks. EPRI and PG&E are also collaborating in designing and constructing a natural-gas-fueled 100-kW MCFC pilot plant at PG&E's San Ramon, California, R&D Center to

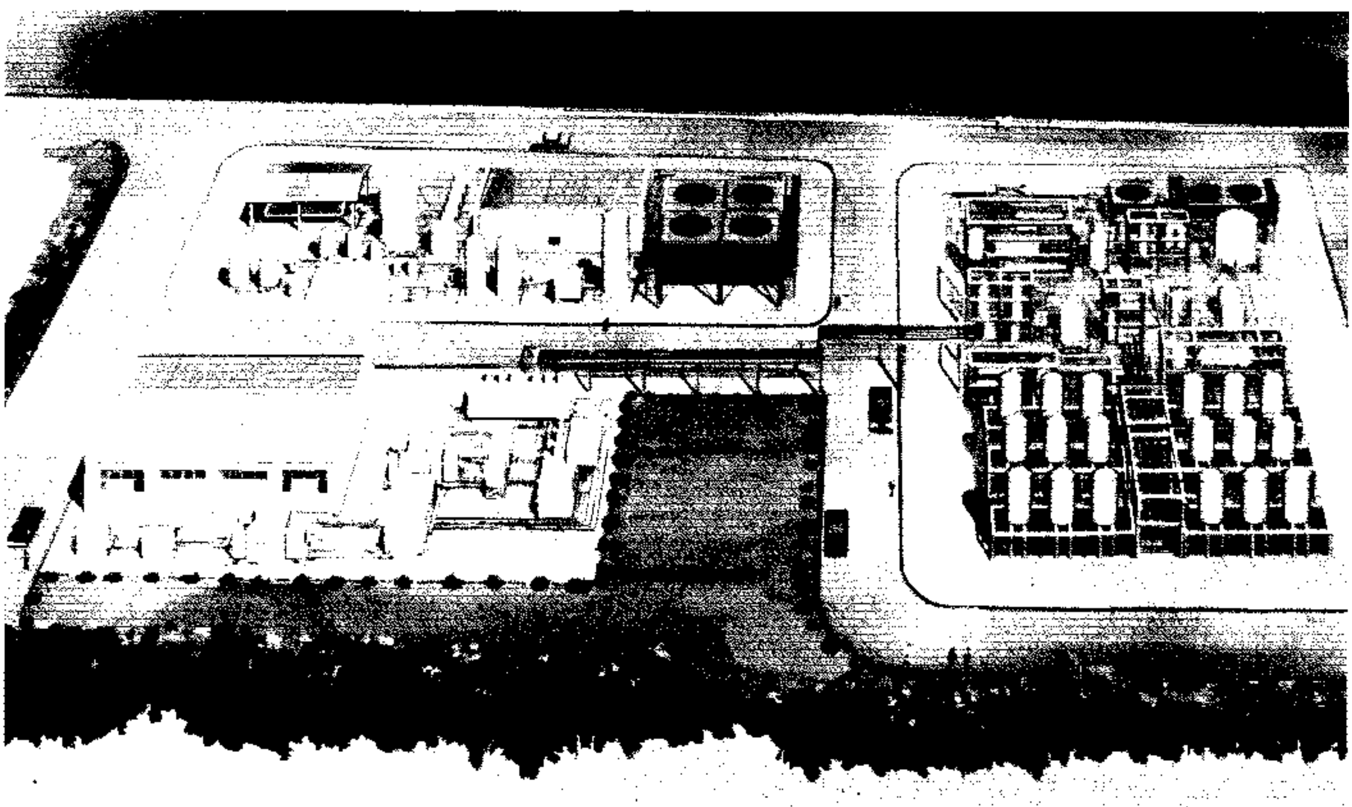


Figure 1 An artist's rendering of the 11-MW phosphoric acid fuel cell power plant under construction at Goi, Japan, by Tokyo Electric Power. Ground breaking for the plant took place in February 1989, and construction will be finished by February 1990.

test ERC stacks. It is believed that this pilot plant, scheduled to be in operation in 1991, will be the first demonstration of a complete MCFC power plant in the world.

PG&E is designing the 100-kW pilot plant to be mechanically simple, even if this means sacrificing some fuel efficiency. The objective is to have the highest possible reliability in the first-of-a-kind plant. The plant is expected to have a net heat rate of about 7000 Btu/kWh (a higher heating value) on natural gas, even though it does not have a bottoming cycle and its efficiency has been compromised in the interest of simplicity.

EPRI has been approached by a European utility about collaborating on a second 100-kW pilot plant, again using a stack manufactured by ERC, with a more sophisticated system that recycles unconsumed fuel to the fuel cell anode. This system could perhaps achieve a heat rate as low as 5600 Btu/kWh. This demonstration, which would confirm the type of process system envisioned for dispersed generators in the 2- to 10-MW class, would follow the PG&E test by about six months and would be a precursor to a possible megawatt-scale plant demonstration in the 1994–1995 time frame. If all testing was reasonably successful, this type of dispersed generator could be commercially available two to three years earlier than planned.

Future directions

EPRI is also collaborating with the Japanese energy agency NEDO (New Energy Development Organization) and five electric companies (Tohoku, Chubu, Chugoku, and Kyushu electric power companies and the Electric Power Development Co.) in a series of conceptual designs by Westinghouse R&D Center for solid oxide fuel cell (SOFC) power plants. Four plant designs will be developed:

- A 300-MW SOFC integrated with a coal gasifier and a steam bottoming cycle
- A 300-MW LNG-fueled SOFC with a bottoming cycle
- A 20-MW LNG-fueled dispersed SOFC generator
- A multimegawatt demonstration-model plant that would serve as a precursor to any of the above plants

According to the collaborative agreement with the Japanese organizations, EPRI will manage the contract with Westinghouse but will be reimbursed for all contract expenditures. Also, DOE and EPRI must approve any material to be provided to the Japanese sponsors, and EPRI can publish reports of the plant designs to make them available to its member utilities.

The total cost of all the Japanese and European demonstrations and evaluations of this predominantly U.S. technology is over $100 million to the foreign participants, a sum much larger than EPRI's cumulative investment in fuel cell technology. Even though demonstrations of advanced utility generation systems are at a low ebb in the United States, EPRI's collaboration with foreign utilities will ensure that demonstration results become available to EPRI members considering capacity additions in the mid-1990s and beyond.

Demand-Side Planning

Industrial Market Information System

by Robert Jeffress, Larry Lewis, and Ray Squitieri, Customer Systems Division

For utilities, the industrial sector represents a large market for new electrotechnologies. Utilities can strengthen their industrial customer base while at the same time increasing or shaping their loads. The electricity-based technologies can provide the greater energy efficiency, better precision and control, and improved productivity and product quality that manufacturing companies seek in order to remain competitive in the world marketplace. What utilities need now is an efficient way to match the new technologies to the right customers.

The industrial market information system (IMIS) is a software package that helps utilities make their industrial marketing efforts more efficient and effective. A key feature of IMIS is its ability to identify and target specific technologies and customers for industrial marketing. IMIS is designed to benefit industrial marketing staff, market planners, customer-service representatives, and energy-demand analysts.

Utilities use IMIS to organize information on 16 new electrotechnologies (ranging from induction heating to freeze concentration) and how they relate to over 450 industries. IMIS also allows utilities easy access to information concerning industrial customers and the best candidate industries and customers for specific technology applications. Another benefit is that it promotes improved interaction and sharing of information throughout the industry.

IMIS is both a data management system and an analysis tool. As a data management system, IMIS organizes and provides access to a utility's information about industrial customers. Utility representatives can use it to obtain up-to-date profiles that will prepare them for customer visits. As an analysis tool, IMIS helps industrial market planners estimate energy-use trends that result from industrial technology changes. It will calculate the potential energy impacts of planning scenarios and allow the user to specify, by industry or by customer, market penetration rates.

Information management

IMIS contains data sets compiled by industry and technology experts for 454 four-digit Standard Industrial Classification (SIC) industries and 16 electrotechnologies. The data sets include the following information:

- Key manufacturing processes by industry

ABSTRACT *IMIS, a new EPRI computer code for industrial market planning, aids utilities in matching industrial customers to specific electrotechnologies. IMIS also estimates the impact of technology changes on kilowatthour sales for an individual, an individual customer, an industry, or the entire industrial sector. Future versions are expected to include conservation, load management, and load-shaping strategies.*

- Percentage of industry energy use by process
- Current and potential applications of key electrotechnologies by industry and by process
- Current and potential market shares of key electrotechnologies by industry and by process
- Names and addresses of leading electrotechnology equipment suppliers
- References and background material by industry and by technology

Specific information on industrial customers becomes an integral part of the IMIS database through user input. These customized files typically include customer name, address, telephone number, account number, dominant four-digit SIC code, annual kilowatthour purchases, and number of employees, as well as product sales and other business information.

IMIS also enables the user to record and track contacts made by customer representatives and other utility staff. The contact records, coupled with the customer-information file, are a useful source of information for review prior to a plant visit.

IMIS gives utility market planners the power to estimate energy-use trends that result from changes in industrial technology. The user can calculate the likely kilowatthour change in sales associated with changing market shares of various electrotechnologies in over 45 industrial processes.

Once the energy impacts of a planning scenario are computed, the data management system allows the user to identify, by industry or by customer, the most promising markets. The resulting profiles can be reviewed to assist utility staffs in preparing for customer visits.

In short, IMIS can be used to estimate electrotechnology-energy impacts at the four-digit SIC level and at the individual or customer level, and then identify industries and customers with significant potential for electrotechnology applications.

Applications and utility experience

IMIS has been designed to operate effectively with three levels of utility data input. In the first level, no utility input is required. The user can gain access to the extensive default data sets that are built into IMIS. These data sets include information on matches between specific technologies and the specific industrial operations where they apply; on technology cost-effectiveness and market share; and on energy use by specific industrial operations.

The second level requires the utility to input data on electricity sales by four-digit SIC group. With this information, IMIS can conduct industry-level analyses that generate lists of technologies and industry segments to be targeted, and estimate the potential electricity-sales impact associated with electrotechnology market penetration.

The third level requires customer-information files containing customer-specific electricity sales data and four-digit SICs. With this information, IMIS can conduct customer-level analyses that generate lists of the individual customers that are the most likely marketing targets, and estimate the potential sales impact on customer electricity use associated with electrotechnology market penetration.

For two years Commonwealth Edison has used IMIS and its predecessor program, FABMET, to direct its marketing efforts with metals fabrication customers. By matching customers with appropriate electrotechnologies, the program allowed the company to shrink its list of 9000 metal fabricators down to a more manageable 350, which were then sorted and distributed to the appropriate field-marketing staff. Within one year, the company's marketers had reported over 55 MW of new industrial load, 15% of which was attributed to the program.

Learning to use IMIS

Using IMIS requires no experience with standard computer packages or programming languages. The system is menu-driven, with help screens available to assist users. The system comes complete with data sets that have been developed for 454 four-digit SICs in the manufacturing sector (SICs 2011–3999). This means that users can immediately begin to learn about relevant industrial processes and technologies. The IMIS databases use dBase III™-compatible files. Data sets are based on the best judgments of industry and technology experts. The process and technology information relates to typical conditions and trends; local and regional characteristics of an industry or customer are substituted as they become available.

The following tools are available to help new users learn about IMIS:

- *IMIS User's Guide,* which includes installation guidelines, as well as step-by-step instructions for each IMIS capability.
- IMIS demonstration program, which includes an overview of the system, a tutorial, and four examples of how IMIS can be used to solve typical marketing problems.
- IMIS context-sensitive help facility, which can be accessed for each menu presented on the screen by pressing the <F1> key.
- IMIS User's Group, which is a forum for exchanging utility experiences, discussing col-

laborative projects, and providing updates on IMIS modifications. Meetings are held in conjunction with other affiliate member program activities.

The IMIS database is designed to include additional industrial-data resources. Many of the following data sets associated with recent and current EPRI projects will be incorporated directly into IMIS:

- The Industrial Data Project will develop a comprehensive database covering business outlook, manufacturing processes, technologies, demand-side management opportunities, and utility options in the industry sector.
- The *Electrotechnology Reference Guide* provides aggregate information on energy use by two-digit SIC group, and on the impacts of electrotechnologies on overall electricity use in the United States.
- The *Industrial Technical Assessment Guide (TAG℠)*, a companion document to the *Electrotechnology Reference Guide,* provides cost, performance, and energy-use data for alternative end-use technology comparisons.
- The Industrial End-Use Planning Methodology (INDEPTH) is designed for individual utilities and can make service-territory forecasts at several levels of disaggregation; the INDEPTH system will facilitate making projections of likely load impacts for key electrotechnologies using a life-cycle cost criterion.
- The Industrial Program Index (IPI) provides a handy PC-based software index of Industrial Program products, services, and current research projects; it can be accessed by industry, electrotechnology, application, or title.

Coal Quality

Laboratory Guidelines for Coal Analysis

by James Hervol, Generation and Storage Division

In 1988, U.S. utilities burned 750 million tons of coal worth $24 billion. To verify that delivered coal meets specifications, utilities collect representative samples, which they send to laboratories for analysis. Because the results of these analyses determine the amount that utilities pay for the coal, the laboratory results must be accurate and precise—even though coal composition is highly variable and therefore difficult to analyze. An error of only 100 Btu/lb can cost a utility $16,000 on a unit trainload of coal. Also, laboratory results must be returned quickly, and for a reasonable cost.

American Society for Testing and Materials (ASTM) coal analysis standards were developed for anthracite and bituminous coals, which until 1970 made up more than 95% of U.S. production. Low-rank coals are much harder to analyze, and they will make up nearly 50% of total U.S. production by 1990. These coals have a higher moisture content, degrade more easily, are more subject to spontaneous combustion, and generally have different chemical constituents than other ranks of coal. In the absence of ASTM standards for low-rank coals, many laboratories have taken the initiative and modified their procedures or developed new methods for analyzing low-rank coal.

To provide guidance in improving the validity of coal analyses for all coal ranks and to help avoid the costly ramifications of inaccurate data, EPRI has developed a multivolume series, *Laboratory Guidelines and Procedures for Coal Analysis* (CS-5644), covering various aspects of coal analysis:

- Volume 1, *Assessing the Cleanability of Fine Coal*
- Volume 2, *Determining Coal Size Distribution by Wet Screening*
- Volume 3, *Establishing and Maintaining a Laboratory Quality Assurance Program*
- Volume 4, *Analyzing Low-Rank Coals*
- Volume 5, *Determining Trace Elements in Coal*

The first three volumes have been published; the final two are in preparation.

ABSTRACT *The types of coal burned by U.S. utilities are changing. Low-rank coals (lignite and subbituminous), which at one time made up 1–2% of U.S. coal production, now make up nearly 40% because of their relatively low sulfur content. They are expected to account for nearly 50% of production by 1990. This shift affects the laboratory, where technicians analyzing coal shipment samples have to modify procedures developed for high-rank coals. EPRI has developed guidelines and standards to improve the validity of coal analyses, a crucial step in determining the value of delivered coal.*

These guidelines are based on over seven years of research at the EPRI Coal Quality Development Center (CQDC) and the experience gained through analyses of thousands of samples of coals of all ranks by the nearby Homer City Coal Laboratory. HCCL—a research laboratory owned by Pennsylvania Electric and New York State Electric & Gas—analyzes all CQDC-generated samples. It is operated under strict quality control.

Volume 1 of the EPRI series details a new procedure for assessing the cleanability of ultrafine (<200-mesh; 1 mesh equals 1 screen opening per inch) coal particles by using a centrifuge. Conventional laboratory procedures use static-bath float/sink methods, in which the coal sample is placed in organic liquids of known density. Once immersed, the lighter particles (coal) rise to the top and the heavier particles (minerals) settle to the bottom. The quantity and composition of the separated coal and the quantity and composition of the impurities that sink reveal the quality and cleaning potential of the coal. These procedures are accurate for most particle sizes but produce inaccurate results for ultrafine coal. Ultrafine particles exhibit slow and erratic separating rates or may not separate at all because of convection currents, electrostatic forces, surface tension, and interparticle forces.

Increased emphasis on reducing SO_2 emissions from coal-fired power stations, advanced coal-cleaning processes that grind coal to a fine powder to improve mineral liberation, and increased quantities of coal fines in the feed to cleaning plants, from mechanized mining processes, have created the need for a reliable method of assessing the cleaning potential of ultrafine coal particles. The new procedure, which uses a centrifuge to speed particle separation, yields more reliable and more accurate results than conventional float/sink methods for ultrafine material (Figure 1). It also decreases turnaround time by a third, resulting in cost savings of up to 35% per test.

Volume 2 describes a new "wet-scalp" method for determining coal size distribution. Conventional laboratory dry-screening procedures yield relatively inaccurate estimates of coal size distribution because clay and moisture in the finer sizes (<28 mesh) cause particles to cling to one another. This leads to overestimating the quantity of coarse coal and underestimating the quantity of fine coal in a sample. In contrast, wet laboratory screening produces accurate estimates by spraying all particles with water, which minimizes agglomeration, packing, electrostatic attraction, and other problems associated with dry fines. However, spraying adds extra steps to the process (including dewatering and drying) and therefore makes the analysis more costly.

The EPRI-developed wet-scalp method combines the speed of dry screening with the accuracy of wet screening. The wet-scalp method, which exposes all material to water at some point, is a combined dry- and wet-screening technique that effectively and economically separates fine particles from coarse particles. The technician first manually wet-screens the sample using a ¾-in wire mesh screen to avoid particle breakage, then screens the ¾-in × 0 material at 28 mesh and 100 mesh by means of a vibrating continuous-screening device. To ensure proper placement of material by size, the technician then subsamples and dry-screens the ¾-in × 28-mesh material, mechanically dry-screens the 28-mesh × 100-mesh material with standard sieves, and mechanically wet-screens the 100-mesh × 0 material with standard sieves. This procedure minimizes the amount of misplaced material, which significantly increases the accuracy of the results (Figure 2). The new procedure is as accurate as wet-screening methods but requires only two-thirds the time, for a cost savings of up to 42% per test.

Volume 3 details a comprehensive coal laboratory quality assurance program that can verify the reliability of coal analyses. Consid-

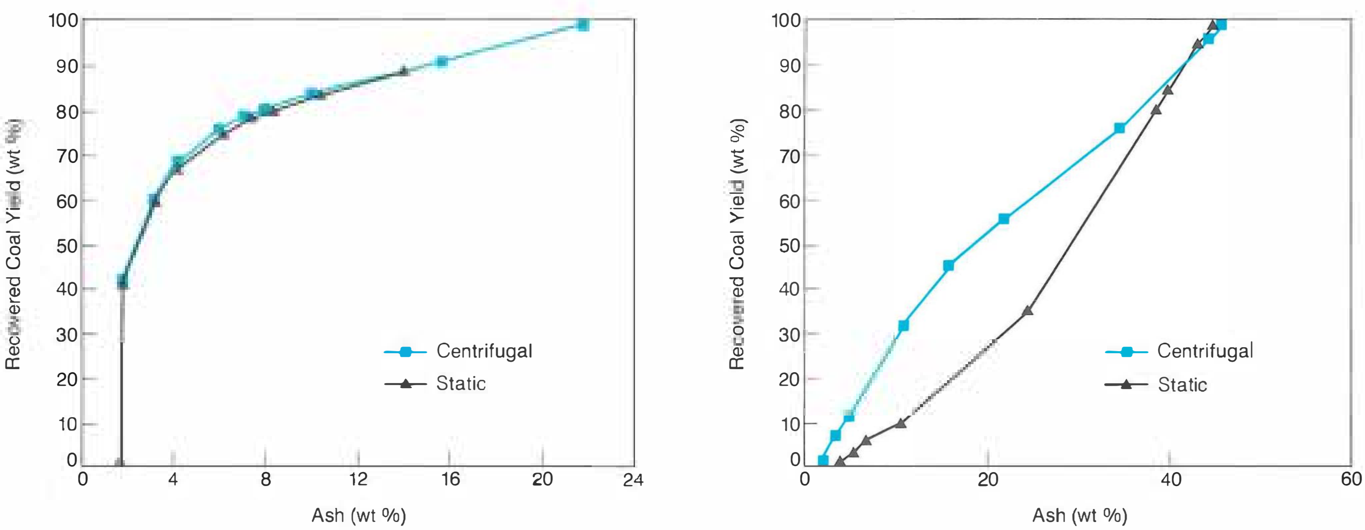
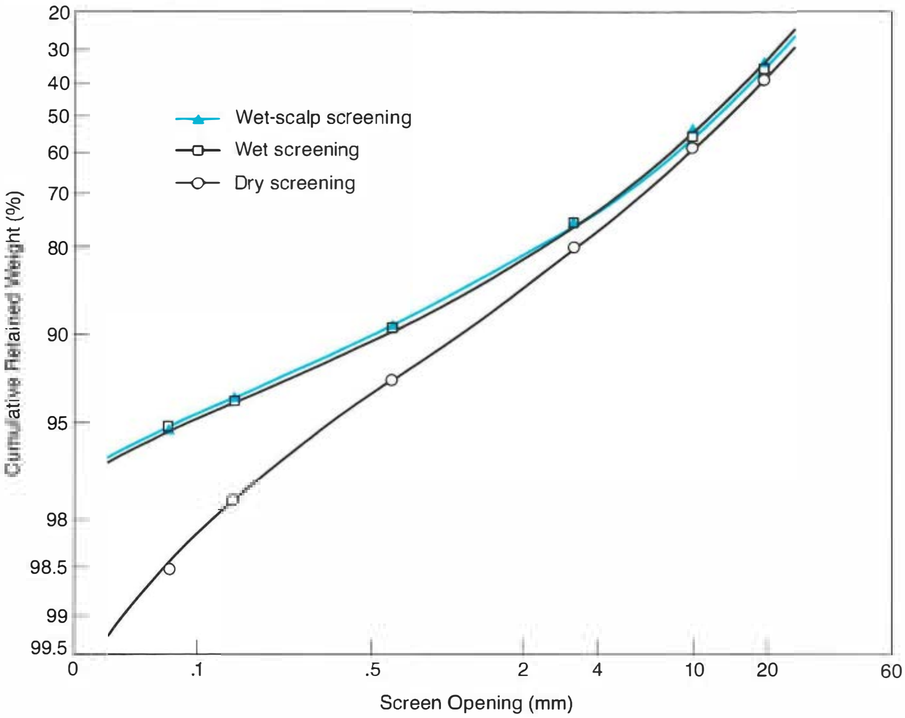


Figure 1 Washability curves for the 100-mesh × 200-mesh fraction (left) are virtually identical for the static-bath and centrifugal float/sink methods. In contrast, there is wide disparity between results for the 200-mesh × 0 fraction (right). The centrifugal method shows higher yields, more closely approximating theoretical estimates.

Figure 2 Size distribution curves from the EPRI-developed wet-scalp screening method are nearly identical to conventional wet-screening results for all coals tested. Dry-screening results are inaccurate at all but the largest sizes.



ering the cost of laboratory errors, quality assurance, which typically costs 10% of a laboratory budget, is a relatively inexpensive way for utilities to ensure that the coal they are burning meets specifications.

This guideline identifies the essential components of a complete quality assurance program, including the necessary personnel and equipment. It also details program implementation and maintenance, illustrating recommended practices with examples of logs, procedures, control sample criteria, and reports. Laboratories can adopt all or part of the guideline, depending on data accuracy and precision requirements.

Volume 4 (to be published in 1989) will describe detailed procedures for handling and accurately testing and analyzing low-rank coals. This guideline will explain alternative procedures and validated modifications to the procedures developed for high-rank coals.

Volume 5 (to be published in 1990) will describe procedures for reliably measuring the concentration of trace elements in coal. All but 16 of the 92 naturally occurring elements have been detected in coal, most at trace concentrations. These elements, which can concentrate in power plant bottom ash and fly ash, can potentially be released into the environment from waste disposal sites.

Current regulations at both state and federal levels set limits for trace element discharge. Therefore current standard analytical methods all include measuring the trace elements in coal ash. This analysis, however, does not provide the means to predict the trace element content of whole coals, an important consideration for utilities that are switching coal sources. The Volume 5 guideline will describe currently practiced and recently developed procedures for accurately determining the concentrations of trace elements in coal. These procedures can help utilities plan steps for meeting current and future trace element regulations.

Transmission Substations

Substation Equipment Diagnostics

By Stig Nilsson, Electrical Systems Division

Recent advances in signal processing techniques have paved the way for utilities to effectively meet the challenge of using existing assets more fully while maintaining traditional service reliability. Over the last 10 years EPRI has been applying these technological advances in the area of transmission substations to develop substation diagnostic devices and systems. EPRI's involvement with transformer diagnostics is seen in the following projects:

- A Fluoroptic™ thermometer for direct transformer temperature measurements (RP1289-1, -3; RP1499-2, -3)
- An acoustic-emission-based partial-discharge detector for power transformers and high-voltage current transformers and potential transformers (RP426-1; RP1497-3)
- A low-cost continuous gas monitor for incipient fault detection in power transformers (RP748-1; RP2445)
- A static electrification monitoring system for large power transformers (RP1499-13)

By monitoring substation equipment, utilities can make more informed decisions regarding equipment maintenance and thus minimize unnecessary downtime. Hence,

ABSTRACT *Accurate and reliable monitoring and diagnostic instrumentation techniques for substation equipment can help utilities minimize maintenance costs, maximize system reliability, and extend equipment life. Toward these goals, EPRI has developed an integrated system for substation relaying and control, in addition to devices that directly measure transformer winding-conductor temperature and transformer partial discharges.*

these systems will reduce equipment maintenance costs, increase system reliability, and extend equipment life.

Fluoroptic thermometer

One development is in the measurement of transformer winding-conductor temperature. In the past, this temperature was only simulated, by using devices that circulated current through a model coil. Although these simulation systems can provide reasonably accurate measurements during moderate overloads, their measurements may be overly conservative during high overloads. In a test on a Southern California Edison 15-MVA transformer, the measurements of a direct-reading hot spot detector were as much as 15°C too high during high overloads, compared with actual measurements. Accurately measuring transformer temperature helps utilities operate with higher overloads without jeopardizing reliability and insulation life.

In 1981, the Fluoroptic thermometer, an independently developed temperature sensor, became available. The thermometer uses a sensitive phosphor-tipped probe that is both simple and small (Figure 1). EPRI has developed a suitable fiber and evaluated installation techniques for using the sensor as a hot spot detector in transformers. EPRI has also sponsored prototype installations in two 20-MVA experimental oil-filled transformers and in a perchloroethylene-filled 65-MVA transformer at a Consolidated Edison substation. These installations have demonstrated the dielectric integrity of the fiber-optic connections to the windings and have helped the supplier improve the device.

Partial-discharge detector

Partial-discharge detectors for transformers are another commercially available product in the equipment diagnostics area. Many transformer failures could be prevented through the early detection of partial discharges that result from incipient faults in the transformer. At the factory, manufacturers use electrical sensing techniques to detect these partial discharges. Such techniques cannot be used on operating transformers, however, because of interference from transmission facilities.

To solve this problem, Cooper Power Systems (CPS), of Franksville, Wisconsin, developed an acoustic-emission-based sensing method for EPRI. The method helps users assess, with the aid of a simple single-channel instrument, the severity of a partial discharge. After pinpointing a low-level source of partial discharge in a transformer, a user can decide whether to repair the transformer in the field or return it to the factory.

Houston Lighting and Power successfully used this instrument to screen high-voltage potential transformers and current transformers. The suspect units were then deenergized in order to remove oil samples for laboratory combustible gas analysis. Additional field tests at the Tennessee Valley Authority will evaluate the feasibility of using a remotely controlled manipulator to position the instrument at the energized tops of current transformers to measure partial discharges.

In a decision unrelated to technical or commercial success, CPS has discontinued the product. However, another EPRI licensee, Hartford Steam Boiler Technologies, of Sacramento, California, introduced a new single-channel unit at the IEEE T&D Conference in New Orleans (Figure 2). This unit is expected to be commercially available in late 1989.

Gas-in-oil monitor

Another current research area is the on-line measurement of combustible gases in transformers. Continuous on-site monitoring of transformers is needed to alert utilities at an early stage to incipient faults in transformers. To detect all possible failure modes, at least two gases must be monitored—hydrogen and carbon monoxide.

In one EPRI project, a gas permeation cell and a chromatographic column separation system were developed and field-tested. This work demonstrated the technical feasibility of the system and led to a decision to develop a monitor that uses low-cost sensors. New metal oxide sensors are being evaluated for

Figure 1 A new device that directly measures transformer winding-conductor temperature, the Fluoroptic thermometer uses a phosphor-tipped probe (foreground).

long-term stability in the presence of oil vapors, high humidity, and temperature variations.

Static electrification monitoring

Static electrification affects the reliability of large shell-form and core-form transformers that have directed-flow forced-oil cooling. By way of a complex Van de Graaff–type generator phenomenon, flowing oil removes ions from the interface with solid materials (such as pressboard in winding ducts) and deposits them at other locations, where they accumulate. As voltage builds, the current leaks back to the source. Because modern forced-cooled extra-high voltage (EHV) transformers are highly insulated, high voltages can result from the electrification process, increasing other stresses and exceeding the dielectric strength of the transformers.

Documented failures in the United States have involved tracking on the insulation at the transformer bottom and 9.5- to 26-inch flashovers in the bulk oil above the windings. Because static electrification tends to lower the withstand voltage of transformers, many undocumented failures are also suspected to have occurred.

EPRI first encountered a static electrification problem in electrical equipment in 1979. Since then, EPRI research has included developing test strategies, design tools, countermeasures to cure and avoid static electrification problems, and monitoring instrumentation. Transformer monitoring equipment expected to be installed late this year will have sensors that measure transformer operating conditions and an absolute-charge probe that extends into the oil directly above some of the winding oil exit ducts. This monitor will help identify long-term trends during transformer operation and help EPRI move toward a solution to static electrification problems.

Digital protective relaying system

In addition to transformer diagnostics, EPRI has developed equipment diagnostics for other substation equipment. One commercially available product, for example, is an integrated system for substation relaying and control.

In a conventional substation, the power apparatus is connected to control subsystems, such as relays, alarms, recorders, and meters. Many separate cables are needed for the connections between the switchyard and control-house circuits. Because most of this wiring is done on site, the cost of the cable and its installation and checkout is a substantial fraction of the substation construction cost. Furthermore, coordinating the operation of subsystems from various manufacturers is time consuming and requires substantial design engineering input.

In 1978, EPRI began to develop an integrated system for the protection, control, and monitoring of substations and associated transmission lines. This project has resulted in a microprocessor-based, integrated system that is currently undergoing tests at Public Service Electric and Gas Co.'s Deans substation (Figure 3). In this system, short cable runs bring signals to data acquisition units that are strategically located in the switchyard. These data are then converted to digital form in the switchyard and transmitted via fiber-optic communication channels to the control house. As a result, field wiring and electromagnetic interference can be reduced, and system performance is improved.

The digital system uses self-checking and detects both protective relay equipment failures and some input sensor failures. To help operators analyze system disturbances and relay-system malfunctions, extensive event records and other data are generated. Digital relays can be installed and checked out in a fraction of the time that is needed for conventional relay systems.

To demonstrate the digital techniques for transmission line protection, matching protective relaying terminals, built from the same hardware and software modules, have been installed at the Branchburg end of the Deans-Branchburg line. Moreover, several stand-alone line-protective relaying systems are being field-tested.

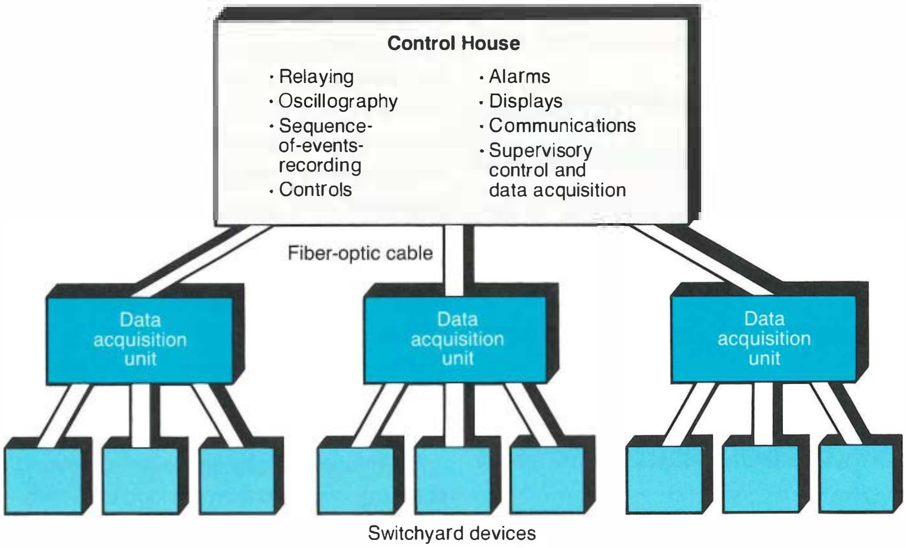
Fault locator for gas-insulated substations

Gas-insulated compact substations (GISs) require less space and are immune to weathering and contamination problems. But existing methods of locating problems when they occur, such as internal corona activity or any breakdown of the insulation system, have been unsatisfactory. For example, ultrasonic detection requires that the faulted segment be reenergized.

Previous EPRI work demonstrated that the location and severity of damage and the range of arc travel during any high-energy

Figure 2 A new partial-discharge detector for transformers is expected to be commercially available from Hartford Steam Boiler Technologies in late 1989.

Figure 3 EPRI's new microprocessor-based, integrated system for the protection, control, and monitoring of substations and associated transmission lines. With the new system, field wiring is reduced.



faults can be assessed by means of an infrared thermal image monitoring technique. Two current EPRI projects based on this technique will develop a system that can locate electrical faults in GIS equipment. In one project, an infrared-sensitive video camera scans, and records on tape, a preset view of the substation when triggered by a fault signal. In a second project, a simpler camera system uses a moving mirror to scan horizontally and vertically in front of a single infrared-sensitive cell. Both systems will be tested at Louisiana Power and Light's Sterlington switching station in late 1989.

Circuit breaker diagnostics

Another area of EPRI substation-related research is circuit breaker diagnostics. Although each of the more than 40,000 U.S. power circuit breakers is infrequently operated, the breakers must be reliable to ensure adequate protection of utility T&D systems. Hence, complete overhauls—a two- to ten-day task—are typically performed every five to ten years. To minimize maintenance costs, a low-cost, reliable method is needed to monitor these breakers and to predict when overhauls are actually needed.

EPRI is developing an advanced diagnostic system that detects changes in the vibration signatures of power circuit breakers. By detecting change, the system attempts to ascertain the mechanical condition of the breaker, including the need for adjustment, without internal inspection. Checking for a variety of potential defects, the system determines the operating condition of key components. A small vibration transducer attached to the wall of the breaker senses the vibrations, and a portable computer with analysis software helps users interpret the signatures.

Still under development, this system is expected to increase breaker reliability and reduce the cost of breaker maintenance and inspection. Furthermore, a preliminary study indicates that application of this technology to transformer load tap changers shows promise.

Electric Technologies

Enhancing Commercial Food Service Equipment

By Karl Johnson, Customer Systems Division

Food service facilities are the most intensive users of energy, per square foot of plant, in the commercial sector, accounting for over $6 billion a year in electricity revenues. An EPRI study in 1986 found, however, that the use of electric models was declining for nearly all commercial cooking equipment; only microwave ovens showed a healthy upward sales trend. The study also identified several efficiency and operating improvements that would increase the value of electrical equipment. Furthermore, the particular food service equipment selected is a major factor in deciding the energy sources of a new site. The EPRI study estimated that each decision to bring gas to a new restaurant represents a loss of about $125,000 in electricity revenues over the life of the restaurant. EPRI has responded by establishing a research plan for the commercial food service area.

National Electrical Code change

The higher first cost of service entrances has long been perceived as a barrier to the expansion of all-electric facilities. Under the existing National Electrical Code (NEC), the total first cost for a service entrance and distribution system in a typical fast-food restaurant can be as much as $9000 higher in an all-electric facility.

EPRI analysis of the U.S. Department of Energy's PREP Study restaurant data showed that electrical service entrances were significantly oversized in seven restaurant types. As a result, EPRI—along with the National Restaurant Association (NRA), the Edison Electric

ABSTRACT *After a study of recent trends showed that electric food service equipment could provide cost-effective customer and utility benefits, EPRI developed a research program to assess and improve the technology and application of both electrical equipment and all-electric facilities. This research effort has yielded a revision of the National Electrical Code, new technical data on energy performance, development of an advanced electric deep-fat fryer, and production of customer-oriented publications.*

Institute, and the Electric Light and Power Group (utility-company code experts)—began a two-year effort to convince code officials that the NEC could be safely revised to allow for streamlined service entrances. Data were collected from over 250 restaurants and other food service facilities across the nation and submitted to NEC Panel 2 in support of this issue.

In January 1989, Panel 2 overwhelmingly approved an optional method for sizing service entrances in new restaurants (Figure 1). In May 1989 this change gained final approval for official adoption, effective January 1990, into the published code. This change will allow many new restaurants to save first costs with smaller service entrances. The first cost for a typical all-electric fast-food restaurant in the Cleveland area, for example, can be reduced by up to $6000.

EPRI and the NRA are preparing an information package on the implementation of the code revision. This information will be available in early 1990 to support EPRI and NRA activities in implementation of the new code.

Test methods and part-load performance

Sponsored in part by EPRI, recent work at Pacific Gas and Electric's Production/Test Kitchen Project has focused on developing methods for testing energy efficiency fairly over a broad range of conditions, including tests that cook real food. These methods will include running equipment at idle and at different operating conditions and will allow utilities and their customers to make better decisions on operating efficiencies and costs. The first of these test methods, for the testing of griddles, is now under review at the American Society for Testing and Materials with EPRI and PG&E support. Test methods for commercial fryers and ovens will be developed in 1989 and 1990.

The efficiency of electrical equipment relative to gas equipment improves as the rate of cooking decreases (Figure 2). Under part-load conditions, flue losses for the gas equipment become a larger percentage of the total energy use, and this reduces efficiency. Previously reported gas-to-electricity energy ratios, which have gained wide exposure and industry acceptance, were based solely on full-load tests and do not reflect the advantages of electrical equipment under typical operating conditions. For example, at idle and for small loads, electric fryers can be three to four times more efficient than gas-fired griddles.

Part-load or idle is by far the more common operating condition for most food service facilities; they operate at those levels at least 75% of the time. As equipment buyers and operators become better educated about how equipment really uses energy, the value of these new research findings will be to correctly characterize the inherently higher efficiencies of electrical equipment.

Advanced electric fryers

The design of most electric food service equipment has not changed much in the last

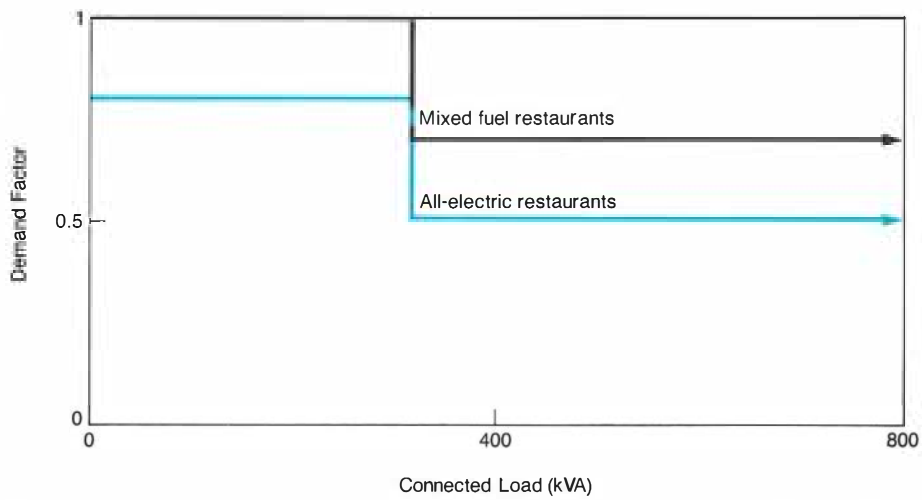
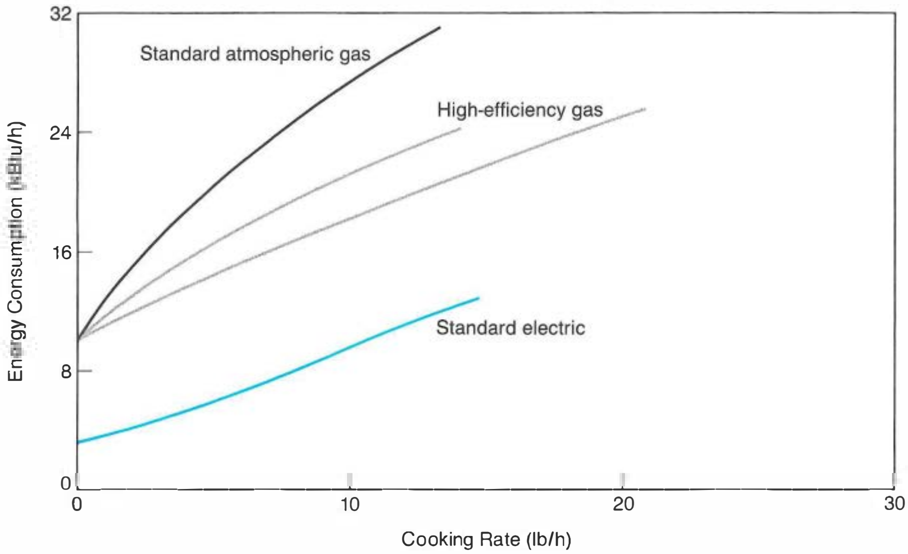


Figure 1 The recently approved National Electrical Code revision, sponsored by EPRI and the National Restaurant Association, allows application of a demand factor (annual peak load divided by total connected load) to the total connected load of both mixed-fuel and all-electric restaurants or food service facilities for purposes of sizing service entrances. The revision is expected to reduce the first costs of all-electric restaurants.

Figure 2 Electrical equipment is more efficient than gas equipment, particularly at part loads. At lower production rates, electric fryers use three to four times less energy than standard gas-fired fryers. At idle, electric fryers use about one-third the energy of gas-fired fryers.



20 years. With the important exception of microwave cooking, most of the innovation in the industry has been in competing fuels. The EPRI food service program is attempting not only to create new pieces of electrical equipment but also to capture the attention of the industry.

Deep-fat fryers were selected for initial research attention because they are the second most commonly owned piece of food service cooking equipment and a major user of energy. Also, electric fryers have several strengths to build upon—they can be insulated on all sides; their heating elements can be in direct contact with the shortening; they are already more efficient than gas equipment (particularly at part loads); and they require less ventilation than gas-fired fryers by at least 20%.

In a landmark agreement for the food service industry, EPRI entered a joint venture with one of the nation's leading fryer manufacturers, Frymaster Corp. The intention is to introduce a new electric fryer at the National Association of Food Equipment Manufacturers show in October 1989 in Dallas. Future research is scheduled to address improvements to all-electric options for griddles, ovens, and ranges.

The relative efficiencies for electric and gas griddles are similar to fryer efficiencies (Figure 2). Electric griddles at full load are twice as efficient as the gas technologies; and at idle and low-load conditions, which are typical of normal operation, electric griddles are as much as three to four times more efficient. Research has also shown that the typical operating load of electric fryers and griddles is about one-fourth the rated input after the initial warm-up period.

New projects

The model-restaurant project, cosponsored by Southern California Edison, is using computer modeling to evaluate four restaurant types (fast-food, cafeteria, full-service, and pizza) in four regions (Atlanta, Cleveland, Phoenix, and Los Angeles). Over 100 electrical enhancements have been evaluated to identify the best options; preliminary results indicate that many of these options are cost-effective. An all-electric kitchen with an engineered ventilation hood is one of the most cost-effective alternatives investigated. The next steps in the project are to complete the evaluation and to work with a food service industry partner to build and monitor a working model restaurant.

Several additional projects are nearing completion, and several new projects are getting under way. Research for a brochure on heat-pump water heaters identified a general need for sound guidance on applications. In response, EPRI is publishing an application guide.

Also in 1989, there will be more equipment testing at PG&E, as well as initial steps toward selecting the next piece of electric food service equipment for R&D funding. The model-restaurant project will begin issuing its findings on improvements to restaurant subsystems and will also initiate plans for constructing one or more model facilities in conjunction with an industry partner. Other new projects include a planned food service symposium in February 1990 designed especially for utility customer-service representatives, and a food service marketing guidebook (produced with the Edison Electric Institute) to assist utilities in understanding how to best serve customers.

New publications

Several new publications designed to help utility customer-service representatives better serve food service customers are now available through EPRI:

▫ *Analysis of Building Codes for Commercial Kitchen Ventilation Systems* (CU-6321): A national study of building, mechanical, fire prevention, and life safety codes that apply to commercial cooking equipment. The review focuses primarily on the design and construction of kitchen exhaust systems and on code revisions that allow more efficient operation of these systems.

▫ *Food Service Sourcebook* (EM-6135): A comprehensive directory of the food service industry, including manufacturers (organized by equipment type), industry leaders, utility contacts, and utility activities; includes a bibliography. A section on recent trends collects information from several leading industry publications. This is the best single-source directory on the food service industry and electric food service equipment currently available.

▫ *The Food Service Industry—A Presentation*

Package With Supporting Text (EM-6148): A booklet with material for two half-hour presentations on the food service industry—one designed to be presented to food service customers, and one designed for in-house utility groups. It contains many industry statistics. The package includes 60 illustrations with supporting text. Slides (35 mm) can be ordered separately.

▫ *Heat-Pump Water Heaters—An Efficient Alternative for Commercial Use* (EU-2020): A brochure on the application of heat-pump water heaters, including a specific discussion of uses in restaurants. This brochure includes a restaurant-application case study.

Nuclear Plant Radiation Control

Radiation Control Technology

by Howard Ocken and Chris Wood, Nuclear Power Division

ABSTRACT *Occupational radiation exposures at U.S. nuclear power plants have been cut in half since 1983. EPRI is currently sponsoring work in every area of radiation-field control, including projects on cobalt-free alloys, zinc injection and pH control, preconditioning of plant components, and full-system decontamination, with the objective of providing utilities with additional cost-effective methods for minimizing exposures in the future.*

Technology to control radiation fields at U.S. nuclear power plants is being implemented at a rapid pace and has helped utilities achieve significant reductions in occupational exposures. Research must move ahead, however, if the downward trend in radiation exposures is to continue.

Radiation exposure trends

Occupational radiation exposures at U.S. nuclear power plants have decreased every year since 1983. Figure 1 shows that whereas total electricity generation from these plants increased by 45.8% from 1985 to 1988, total man-rems decreased by 8.0%. During this same period, the number of man-rems incurred to produce 1 MW-yr of electric power decreased by 32% for PWRs and by 57.5% for BWRs. The overall ratio for LWRs is now 0.68 man-rem/MW-yr, less than 40% of the peak value reached in the early 1980s.

New plants entering the database are partly responsible for the decrease in exposures. Between 1985 and 1988, 20 new plants entered the database, giving a total of 97 in 1988. Another 10 plants were operating but had not completed one full calendar year of commercial operation by the end of 1988. However, exposures at older plants also are declining. Consider the 45 PWRs and 23 BWRs that went into operation before 1980. For these two types of plant, comparison of the 1988 exposure with the average for 1980–1983 shows reductions of 43% and 50%, respectively (Figure 2). Although exposures at U.S. plants are still higher than in other industrial nations with large nuclear programs, the gap is narrowing at a promising rate.

The nuclear industry's success in reducing exposures can be attributed to three factors: (1) improved plant performance, necessitating less maintenance, repair, and equipment modification; (2) increased productivity of workers in the radiation zone, resulting from improved radiation protection procedures and the use of robotic devices; and (3) the use of advanced technology to reduce radiation fields. Even though the impact of each factor has varied widely from plant to plant, industrywide the three factors have probably contributed approximately equal benefits over the past few years.

The data in Figure 2 suggest that the rate of decline in exposures is slowing, perhaps because the main benefits from factors 1 and 2 have already been achieved. However, the full potential from factor 3 has yet to be realized. In the future, reduction in radiation fields will be even more important if the nuclear industry is to continue to reduce occupational exposures and particularly to control exposures of key workers.

Radiation-field control technology

There are four means of radiation-field control, which relate to the fundamental processes involved in the activation, transport, and deposition of cobalt-containing material in primary systems. (Cobalt-60 causes most of the radiation exposure in light water reactors.) The most successful plant control programs feature at least three of the four means, which are briefly outlined below.

Reducing the source There are two ways to reduce the source of the cobalt-containing products of wear and corrosion that can become radioactive and lead to radiation-field buildup: minimizing the cobalt impurities in the structural alloys used for reactor components, and substituting cobalt-free hard-facing alloys for the cobalt-based ones that are typically used in nuclear valves and other components requiring superior wear resistance.

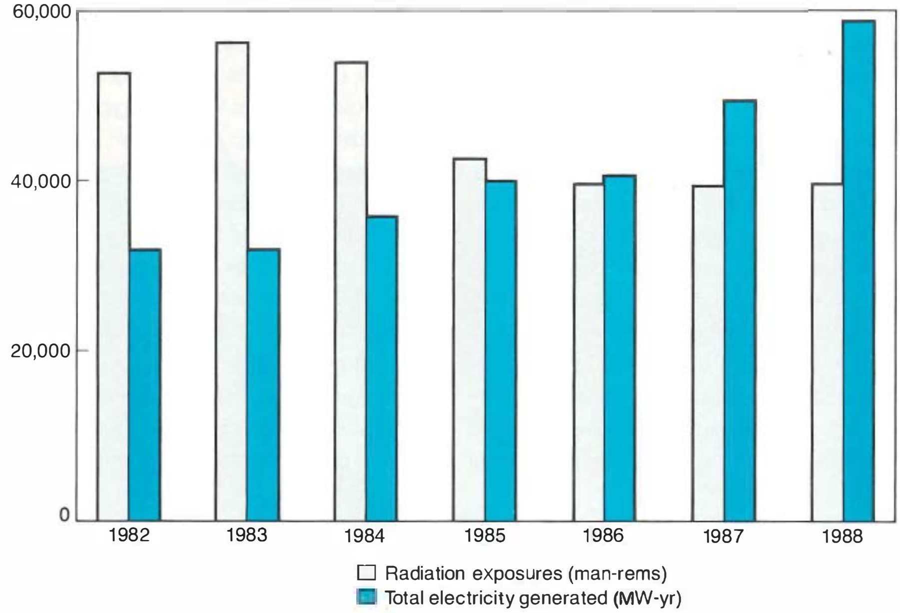
Low-cobalt Inconel tubing has recently been specified for use in replacement steam generators. Stainless steel with a very low cobalt-impurity level is offered by one vendor for use in BWR control blades.

Alternatives to cobalt-based alloys are already being used successfully in the pins and rollers of BWR control blades and in flow control valves. In addition, EPRI-sponsored research has led to the development of a wear-resistant, iron-based hard-facing alloy designated NOREM. This alloy and two other iron-based ones have been deposited on gate valves that are currently undergoing long-term endurance tests. Other ongoing work includes the development of repair procedures for these new alloys and guidelines to assist utilities in implementing the new alloys and in identifying valve types and systems where cobalt-based alloys are unnecessary.

Controlling transport and activation Good water chemistry is the key to minimizing the formation and release of corrosion products into reactor water. It is notable that there is a strong correlation between the absence of radiation hot spots in crud traps in BWRs and good water chemistry. The discovery that a parts-per-billion concentration of zinc in BWR water reduces the release of soluble corrosion products and inhibits the subsequent deposition of cobalt-60 has led to the use of zinc injection at five BWR plants. Radiation-field buildup at those plants was reduced by approximately 50%, and recent experience shows that early problems with zinc-65 activity have been overcome.

For PWRs, pH control is vital to avoiding the activation of corrosion products as a result of in-core deposition. Steam generator fields at plants using elevated pH are 1.5–3.0 times lower than at those using standard chemistry. Research is under way to determine how far the pH can be increased without impairing the integrity of fuel cladding and steam generator tubing.

Figure 1 Radiation exposures and power generated at U.S. nuclear power plants, 1982–1988. On the basis of man-rems/MW-yr, exposures have been steadily declining since 1983.



Controlling out-of-core deposition The preconditioning of primary-system surfaces, either before plant startup or before the installation of replacement components, can significantly reduce the deposition rate of activated corrosion products. There are two main methods of preconditioning: surface modification by mechanical or electrochemical polishing, and chemical preoxidation to develop a passive oxide film before the surface is exposed to reactor coolant. A combination of electropolishing and wet-air preoxidation

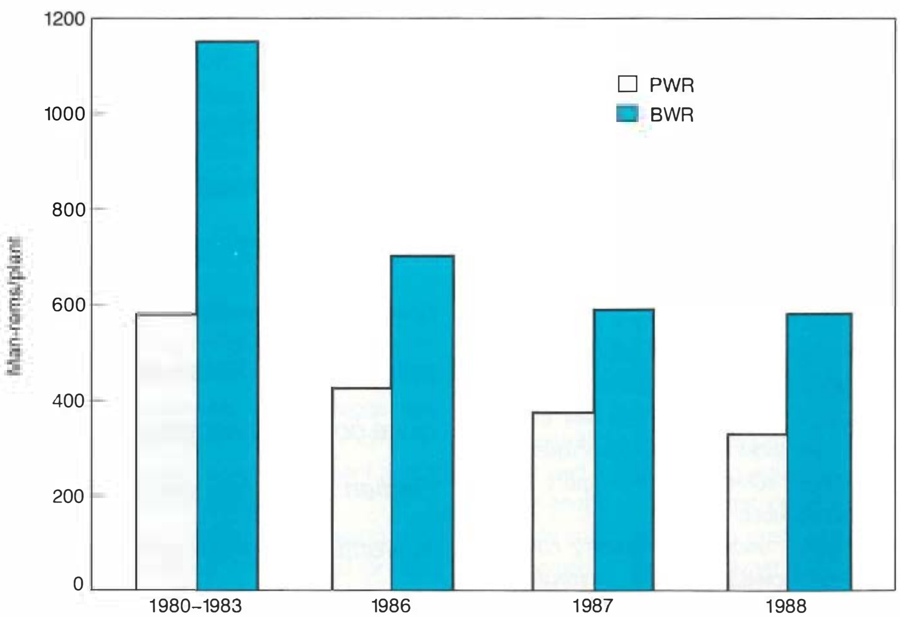


Figure 2 Radiation exposures at plants operating before 1980. These plant averages are based on data from 45 PWRs and 23 BWRs.

gives the lowest recorded rates of recontamination on replacement recirculation piping systems in BWRs. All recent pipe replacements have used electropolished piping, and the majority have also used preoxidation.

On the basis of this successful experience, EPRI has sponsored development and qualification programs to apply surface modification techniques to new or replacement PWR steam generator channel heads. A recently completed program yielded data showing electropolishing to be an acceptable technique for PWR steam generator surfaces. Metallurgical integrity of the weld overlay was found to be unaffected by a wide range of electropolishing parameters. Several utilities are now considering surface conditioning of replacement steam generator channel heads.

Decontamination Radioactive deposits can be removed by mechanical or chemical decontamination; the former is used for small areas or components, and the latter for reactor coolant systems. For existing plants with high radiation fields, part-system chemical decontamination has proved highly cost-effective. The piping systems in the majority of older BWRs have now been decontaminated at least once, and several three times. For these decontaminations the LOMI (low-oxidation-state metal ion) process has been the most popular over the past three years. Steam generator decontaminations have been less common; they are more expensive because of the need for nozzle dams.

A recent feasibility study, however, showed that full-system decontamination (FSD) will be more efficient than the current part-system decontamination and will permit major work to be carried out with low radiation exposures. The study concluded that FSD is cost-effective for both BWRs and PWRs, provided that it is part of a major outage during which other inspection, repair, or replacement work is undertaken.

A subsequent study has been initiated with nuclear steam supply system vendors to address any other outstanding technical and licensing issues related to FSD. It is expected that the results from this study will, by the early 1990s, encourage U.S. utilities to perform FSD with the fuel removed.

Low-Volume Waste Management

Managing Spent Solvent Waste

by Tom Lott, Generation and Storage Division

ABSTRACT *Spent solvent wastes are generated from such routine utility operations as parts cleaning, paint stripping, and vehicle maintenance. These solvent wastes typically are hazardous and require costly management and disposal. An EPRI-sponsored study with Radian Corp. has shown that reducing solvent use, recycling spent solvents, and employing other waste minimization strategies are cost-effective alternatives to hazardous waste disposal.*

For utilities and other equipment-intensive industries, halogenated and nonhalogenated organic solvents are the preferred solvents for removing oil, grease, paint, and dirt from metal parts and machinery. A 1987 EPRI report, *Manual for Management of Low-Volume Wastes From Fossil-Fuel-Fired Power Plants* (CS-5281), identified spent solvents as one of the few types of power plant waste likely to be classified as hazardous. Furthermore, past disposal options have been eliminated by recent changes in hazardous waste management regulations; in particular, the disposal of hazardous solvent wastes in landfills has been banned in most instances. Because the remaining disposal options are expensive and regulations are still evolving, utilities are looking for new techniques to reduce both solvent use and spent solvent waste production.

To better understand industry concerns, EPRI conducted a survey of the solvent management practices of representative member utilities. The survey collected information from 29 utilities (representing 56 operating facilities) on the types and quantities of solvents used, their principal applications, and the costs associated with spent solvent disposal. Most of the responding power plants, operating districts, service centers, and vehicle maintenance shops typically generated less than 300 gallons of solvent wastes, or about 6 drums, per month. The principal solvent uses were parts cleaning in soak tanks, electrical contact cleaning, paint stripping, vehicle maintenance, and burner tip cleaning.

Waste management options

Many utilities have already initiated programs to minimize solvent wastes. Typical steps toward waste minimization include source reduction (e.g., by decreasing solvent usage), substitution of less-toxic materials, and recycling of used materials. EPRI and Radian Corp. have prepared a spent solvent management report that more fully describes these options. The full report will be available later this year.

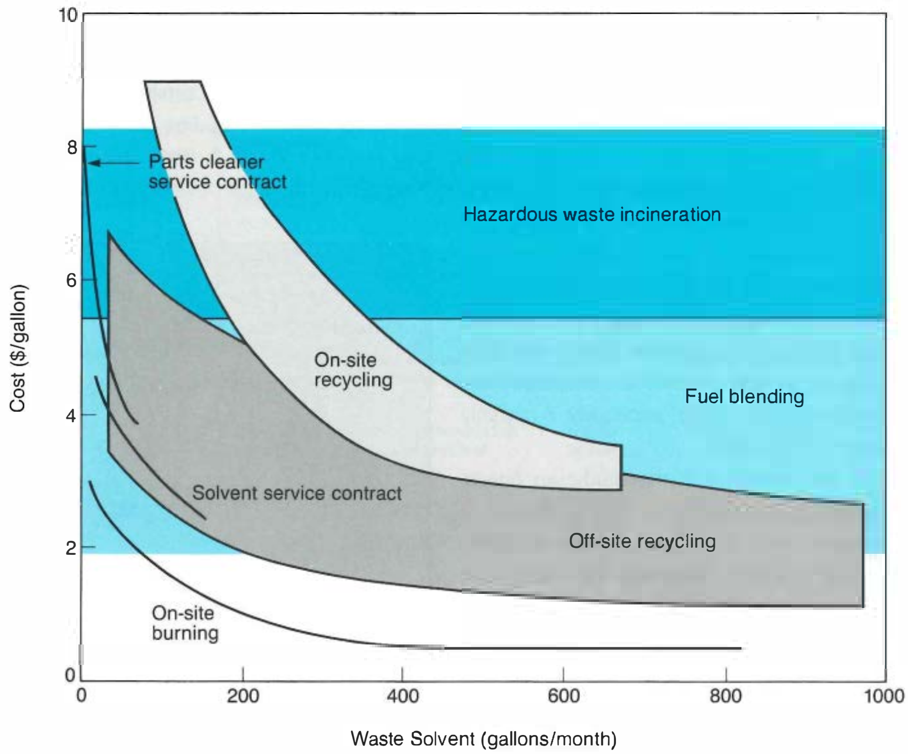
Solvent reduction is the simplest, and often the least expensive, waste minimization option. Training workers to use solvents efficiently, limiting the availability of solvents at facilities, and maintaining good housekeeping practices are the key methods of reducing solvent use. Particular emphasis should also be placed on using less solvent for spill cleanup, because even small amounts of solvent can contaminate spilled materials and render the entire mixture hazardous.

Other reduction measures include decreasing solvent vapor losses from parts-washing equipment by installing covers or equipment enclosures; installing countercurrent multistage cleaners; and containing solvents. These provide the added benefit of reducing worker exposure to solvent vapors.

Several utilities have experimented with using a single universal solvent, typically either mineral spirits or 1,1,1-trichloroethane, to replace the wide variety of products previously purchased. A universal solvent is generally selected such that it is less toxic than the materials previously used. Additional advantages include reduced purchasing costs, worker exposure to a smaller number of potentially toxic substances, and simplified waste reporting and recycling.

A variety of nontraditional substitutes are available to replace halogenated organic solvents. Alternative chemical cleaners include aqueous alkaline solutions of sodium carbonate or sodium phosphate, finely dispersed mineral spirits emulsion cleaners in aqueous solution, and the citrus-based D-limonene organic cleaners. Costs for substitutes range from $0.50 to $0.60 per gallon for emulsions, $0.80 to $2.40 per gallon for aqueous cleaners, and $9.50 to $17.00 per gallon for citrus-based chemicals. Traditional solvents cost $2–$6 per gallon for virgin solvent, plus $1–$8 per gallon for waste disposal or recycling. Substitutes are generally less

Figure 1 Waste solvent recycling costs. In general, disposing of spent solvents as hazardous wastes tends to be the most expensive form of waste management; it may cost four times as much as off-site recycling. While for small amounts of solvent on-site recycling is expensive, parts cleaner and solvent service contracts can be cost-effective.



toxic but in some cases less effective and more corrosive than traditional solvents. Effectiveness is particularly important for electrical contact cleaning, where residues are not acceptable. New cleaning formulations should be carefully evaluated to ensure that these products are compatible with their intended uses.

Mechanical cleaning (e.g., sand or bead blasting) can be substituted for chemical cleaning in many instances. Small mechanical blast-cleaning systems are cost-competitive if they displace at least 30 gallons per month of solvent usage; however, bigger systems (e.g., large-capacity blasting rooms) require a significant capital investment and a high use rate to be cost-effective.

Furthermore, mechanical cleaning systems have limitations; though good for paint stripping, these systems are poor degreasers and are not suitable for sensitive material surfaces (e.g., wood, plastic, soft metal) and small, intricate parts. Ultrasonic cleaning can be used to clean small parts or to enhance solvent effectiveness in enclosed washing equipment.

Solvent recycling

In most cases, recycling spent solvent waste is less expensive than disposing of it as a hazardous waste (Figure 1). Utilities have several options for recycling solvents; in fact, 46% of the utility survey respondents already use some kind of recycling. Parts cleaner or solvent service contracts are frequently used to recycle small quantities of solvents. Under these contracts a vendor may provide the solvent as well as the cleaning equipment; the vendor changes the solvent on a regular schedule and transports the waste to a recycling center, where the solvent can be reclaimed. The solvent and equipment are, in effect, leased to the utility. The utility, however, as generator of the waste, is ultimately responsible for the safe disposal of the wastes or residuals associated with recycling.

The ultimate responsibility for wastes is a difficult regulatory issue. In general, because recycling does not eliminate long-term waste liability, it is important for solvent users to be certain that they are working with reputable recyclers.

On-site recycling allows a utility to more fully control the solvent waste stream. However, survey data showed that only a few utilities recycle solvents on site. Since the purchase price for a 10–40-gallon-per-hour distillation system may range from $5000 to over $30,000, most utilities find on-site recycling to be too expensive compared with commercial recycling, especially if monthly solvent use is small.

In conjunction with this study, an on-site recycling demonstration conducted at a western utility showed that used trichloroethane could be reclaimed with better than 80% recovery. Product quality was acceptable but was affected by water contamination in the waste solvent.

Disposal of spent solvents as hazardous wastes may be the only option for solvents that are too heavily contaminated for recycling or reuse. In cost comparisons based on utility survey responses, waste recycling appears to be less costly than hazardous waste incineration. Some utilities employ such lower-cost disposal options as the burning of solvent as supplemental fuel, or the blending of waste with fuel.

Federal regulations concerning waste-derived fuel are now under revision and may become significantly more stringent in the future. Waste fuel burning may have to be re-evaluated in light of these changing regulations.

Future directions

Other utility low-volume wastes may soon face regulatory scrutiny similar to that faced by spent solvents. Studies currently under way in EPRI's Waste & Water Management Program are aimed at developing waste minimization alternatives for a broad range of wastes: boiler chemical cleaning waste, contaminated soil, ethylene glycol, asbestos, and treated wood are a few of the 30 or more wastes under investigation. A series of reports describing waste management options for these other materials will be published later this year; additional research is planned to develop innovative waste minimization strategies for hard-to-manage wastes.

CORRECTION

One column of the table shown on page 43 of the June 1989 issue was omitted. The complete table is shown below.

Table 1
PROJECTED SENSITIVITY OF TTFMS TO VARIOUS SMALL MOLECULES

Molecule	Frequency (1/cm)	Wavelength (micrometers)	Minimum Detectable Concentration (ppt)
H_2O_2	1284	7.788	1.01
HNO_3	1722	5.807	0.32
NH_3	1050	9.524	0.15
PAN	1150	8.696	1.73
NO_2	1604	6.234	0.28
NO	1880	5.319	3.68
CH_4	1300	7.692	0.98
CO_2	2350	4.255	0.05
CO	2120	4.717	0.14
N_2O	3492	2.864	2.61
HCN	712	14.045	0.05
PH_3	992	10.081	0.33

New Contracts

Project	Funding/ Duration	Contractor/EPRI Project Manager
Customer Systems		
NiFe Battery Market Assessment Study (RP2415-9)	$108,700 9 months	Research Triangle Institute. Inc./*T. Henneberger*
Net Benefits of Electric Vehicles (RP2664-13)	$99,500 9 months	Resources for the Future, Inc./*P. Hanser*
Advanced Freeze Concentration of Dairy Products (RP2782-2)	$942,700 36 months	Dairy Research Inc./ *K. Armarnath*
Alternatives to Cogeneration–Industrial Case Studies (RP2783-17)	$160,000 9 months	TENSA Services Inc./ *K. Amarnath*
New Chemical Alternative Refrigerants (RP2792-15)	$166,600 28 months	University of Tennessee/ *P. Joyner*
Advanced Motor/Drive Technology for HVAC and Appliance Applications (RP2792-19)	$86,000 6 months	Tennessee Center for Research and Development/*A. Lannus*
Residential Energy Usage Comparison Project (REUC), Phase III (RP2863-3)	$260,000 24 months	Quantum Consulting/ *S. Braithwait*
Update National Demand-Side-Management Impact Report (RP2863-8)	$70,600 9 months	Barakat, Howard & Chamberlin Inc./*S. Braithwait*
Food Service Marketing Guidebook (RP2890-11)	$58,800 12 months	Synergic Resources Corp./ *K. Johnson*
Feasibility Assessment of Community Ground Loops (RP2892-9)	$50,500 7 months	The Fleming Group/ *P. Joyner*
Electrical Systems		
Fiber-Optic Current and Voltage Sensors for Distribution Systems (RP2734-3)	$355,800 17 months	Optical Technologies Inc./ *J. Porter*
Fiber-Optic Current and Voltage Sensors for Distribution Systems (RP2734-4)	$384,400 15 months	Optra Inc./*J. Porter*
Flexible AC Transmission System (FACTS): Phase 1A, Scoping Study (RP3022-1)	$220,600 12 months	Power Technologies Inc./ *D. Maratukulam*
Flexible AC Transmission System (FACTS): Phase IB, Scoping Study (RP3022-2)	$270,200 14 months	General Electric Co./ *D. Maratukulam*
Distribution Workstation—Specifications (RP3079-1)	$182,900 12 months	Power Technologies, Inc./ *H. Ng*
Bare Overhead Conductor Materials (RP4000-3)	$91,000 7 months	Power Technologies, Inc./ *R. Kennon*
An Investigation of the Interfacial Bond Strength of Polymeric Laminates (RP7880-8)	$62,600 14 months	Johns Hopkins University/ *B. Bernstein*
Development of Composite, Lightweight Trench Cover Plates (RP7910-3)	$184,600 12 months	Foster-Miller Associates Inc./*T. Rodenbaugh*
Internal-Pipe-Joining Press for Pipe-Type Transmission Cables (RP7910-4)	$346,200 18 months	Foster-Miller Associates Inc./*T. Rodenbaugh*
Light-Metal Hydrides and Superconductivity (RP7911-3)	$100,000 12 months	Purdue Research Foundation/*M. Rabinowitz*
High-Temperature Superconductors (RP7911-8)	$544,600 29 months	Northwestern University/ *W. Bakker*
Fundamental Studies on Critical Current Density in Materials (RP7911-9)	$906,600 60 months	Stanford University/ *D. Sharma*
Superconducting Transmission Initiative (RP7911-10)	$720,400 26 months	Underground Systems. Inc./*D. Sharma*
Applications of Oxide Superconductors for Electric Power (RP7911-11)	$604,700 33 months	University of Maryland/ *T. Rodenbaugh*

Project	Funding/ Duration	Contractor/EPRI Project Manager
Environment		
Environment Division Marketing Support (RP2030-27)	$69,900 11 months	Science and Technology Management Inc./ *S. Lindenberg*
Evaluation of Mixing and Plume Penetration Depth at the Groundwater Table (RP2938-1)	$312,500 21 months	Auburn University/ *D. McIntosh*
Biological Studies of Manufactured-Gas-Site Wastes (RP2963-1)	$109,300 12 months	Roth Associates Inc./ *L. Goldstein*
Technology Transfer and Information Services for Studies of Electric and Magnetic Fields (RP2964-6)	$57,800 10 months	Robert S. Banks Associates Inc./*R. Black*
Microcomputer Modeling—Interaction of Low-Frequency Magnetic Fields With Biological Objects (RP2965-9)	$59,700 34 months	University of the South/ *C. Rafferty*
Project 2, Town Gas Waste Site Risk Management Experience Synthesis (RP3076-4)	$197,300 33 months	Atlantic Environmental Services Inc./*V. Niemeyer*
Generation and Storage		
Lessons Learned With Residential Photovoltaic Systems (RP1607-15)	$119,200 9 months	Ascension Technology/ *F. Goodman*
Project Coordination for APPA and EPRI Evaluation of Fuel Cell Commercialization Initiatives (RP1677-18)	$62,700 8 months	Technology Transition Corp./*E. Gillis*
Enhanced Tubes for Steam Condensers (RP1689-21)	$55,000 22 months	Pennsylvania State University/*J. Tsou*
Field Tests of Advanced Electrostatic Precipitator Concepts (RP1835-17)	$436,800 20 months	Southern Research Institute/*R. Altman*
Field Tests of a Full-Scale Two-Stage ESP (RP1835-18)	$155,700 21 months	ADA Technologies Inc./ *R. Altman*
Monitoring Impacts of Coal Quality on Power Plant Equipment (RP1891-4)	$2,198,600 24 months	Electric Power Technologies, Inc./*A. Mehta*
Gamma Scatter Sensor for Wall Thickness Measurement (RP1893-10)	$121,300 12 months	Spire Corp./*S. Gehl*
Development of AFBC Cost-Estimating Guidelines (RP2303-22)	$274,000 17 months	United Engineers & Constructors, Inc./ *S. Tavoulareas*
Nuclear Power		
Piping Analysis Methods Validation Using the Tadotsu High-Level Response Data (RP1444-15)	$104,100 7 months	Rockwell International Corp./*H. Tang*
Behavior of Irradiated Fuel During Wet Storage (RP2062-15)	$65,100 27 months	Atomic Energy of Canada Ltd./*R. Lambert*
Motor-Operated-Valve Test Program (RP2233-9)	$177,000 15 months	MPR Associates, Inc./ *J. Hosler*
Emergency Operating Procedure Tracking System Evaluation (RP2347-22)	$50,000 9 months	Accident Prevention Group Inc./*K. Sun*
Characterization and Stochastic Modeling of Faulting Mechanisms in California (RP2356-51)	$85,000 12 months	Stanford University/ *J. Schneider*
Formulation of Strategies, Technical Bases, and Procedures for Resolution of Seismic Severe-Accident Policy (RP2356-52)	$133,000 10 months	Risk Engineering Inc./ *C. Stepp*

New Technical Reports

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

CUSTOMER SYSTEMS

Evaluation of Electric Vehicle Battery Systems Through In-Vehicle Testing: Fourth Annual Report

CU-6330 Final Report (RP1136-27); $100
Contractor: Electrotek Concepts, Inc.
EPRI Project Manager: R. Swaroop

Assessment of Unitary Cool Storage Systems

CU-6376 Final Report (RP2732-21); $100
Contractor: Ayres Ezer Lau, Inc.
EPRI Project Managers: D. Geistert, R. Wendland

Information and Automation Technology: Serving Electric Utility Customers in the 1990s

CU-6400 Proceedings (RP2597-13); $100
Contractor: Policy Research Associates, Inc.
EPRI Project Manager: V. Rabl

ELECTRICAL SYSTEMS

Electromagnetic Transients Program (EMTP), Vols. 2–4

EL-4651 Final Report (RP2149-6); Vol. 2, $47.50; Vol. 3, $32.50; Vol. 4, $40
Contractor: University of Wisconsin at Madison
EPRI Project Manager: M. Lauby

Distribution Transformer Basic Insulation Level Reduction: Feasibility Study

EL-6426 Final Report (RP2875); $25
Contractor: McGraw-Edison Co.
EPRI Project Managers: W. Kubicki, J. Porter

Performance Indexes for Predicting Voltage Collapse

EL-6461 Final Report (RP1999-10); $32.50
Contractor: Drexel University
EPRI Project Manager: N. Balu

Mutual Design—Overhead Transmission Lines and Railroad Facilities: Susceptibility Program

EL-6462-M Final Report (RP1902-6); $32.50
Contractor: Science Applications International Corp.
EPRI Project Manager: J. Hall

EXPLORATORY RESEARCH

The Selective Oxidation Desulfurization Process: Bench-Scale Studies

ER-6366 Final Report (RP8003-6); $25
Contractor: Battelle, Columbus Division
EPRI Project Manager: L. Atherton

GENERATION AND STORAGE

Arapahoe Low-Sulfur-Coal Fabric Filter Pilot Plant: Volume 4, Shake-Deflate Cleaning Tests, May 1984–July 1986

GS-3862 Final Report (RP1129-8); $25
Contractor: Southern Research Institute
EPRI Project Managers: R. Chang, W. Piulle

Gas Turbine Characterization and Diagnostic Instrument Evaluation

GS-6022 Final Report (RP2102-17); $47.50
Contractor: Battelle, Columbus Division
EPRI Project Managers: L. Angello, G. Quentin

Proceedings: Second Fossil Plant Cycle Chemistry Conference

GS-6166 Proceedings (RP2712); $62.50
EPRI Project Manager: B. Dooley

Field Testing of Behavioral Barriers for Fish Exclusion at Cooling-Water Intake Systems: Ontario Hydro Pickering Nuclear Generating Station

GS-6246 Final Report (RP2214-5); $32.50
Contractors: Ontario Hydro; Lawler, Matusky & Skelly Engineers
EPRI Project Manager: W. Michelletti

Proceedings: Eleventh EPRI Geothermal Conference and Workshop—Basis for Expansion

GS-6380 Proceedings; $40
EPRI Project Managers: E. Hughes, V. Roberts

Design Guidelines for a Furnace Sorbent Injection Waste Management System

GS-6382 Final Report (RP2708-1); $800
Contractors: Baker/TSA, Inc.; ICF Northwest
EPRI Project Manager: D. Golden

Causes of FGD Construction Material Failures, Vols. 1 and 2

GS-6396 Final Report (RP2248-2); Vol. 1, $55; Vol. 2, $47.50
Contractor: Radian Corp.
EPRI Project Manager: P. Radcliffe

The DYNAMICS Model for Measuring Dynamic Operating Benefits

GS-6401 Interim Report (RP2999-6); $32.50
EPRI Project Manager: B. Louks
Contractor: Decision Focus Inc.

Characterizing Fuels for Utility-Scale Atmospheric Fluidized-Bed Combustors, Vols. 1 and 2

GS-6402 Interim Report (RP718-2); Vol. 1, $75,000; Vol. 2, $75,000
Contractor: Babcock & Wilcox Co.
EPRI Project Manager: E. Petrill

U.S. Coal Test at the PRENFLO Demonstration Plant

GS-6403 Final Report (RP1654-39); $25
Contractor: Gesellschaft für Kohle-Technologie mbH
EPRI Project Manager: N. Hertz

Staged Combustion for Reduced NO_x Emissions From an Atmospheric Fluidized-Bed Combustor

GS-6404 Topical Report (RP718-2); $10,000
Contractor: Babcock & Wilcox Co.
EPRI Project Manager: E. Petrill

A Comparison of Steam-Injected Gas Turbine and Combined-Cycle Power Plants: Technology Assessment

GS-6415 Final Report (RP2387-4, -5); $55
Contractors: Jersey Central Power & Light Co.; Sargent & Lundy
EPRI Project Manager: A. Cohn

Hydropower Plant Modernization Guide—Volume 3: Automation

GS-6419 Final Report (RP2602-2); $400
Contractor: Black & Veatch/Motor Columbus, Associates
EPRI Project Manager: D. Morris

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Contractors: Georgia Institute of Technology; Michigan State University
EPRI Project Manager: J. Maulbetsch

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GS-6431 Interim Report (RP2422-19); $32.50
Contractor: GAI Consultants, Inc.
EPRI Project Manager: D. Golden

Gasification of Lignite and Wood in the Lurgi Circulating Fluidized-Bed Gasifier

GS-6436 Final Report (RP2656-3); $40
Contractor: Lurgi GmbH
EPRI Project Manager: M. Epstein

Trace Metal Removal by Iron Coprecipitation: Field Evaluation

GS-6438 Final Report (RP910-3); $47.50
Contractor: Brown and Caldwell
EPRI Project Managers: M. McLearn, W. Chow

Long-Term Leaching Tests With Coal Gasification Slag

GS-6439 Final Report (RP2659-2); $40
Contractors: Radian Corp.; Tennessee Valley Authority
EPRI Project Manager: N. Hertz

Service Embrittlement of Gas Turbine Blade Alloys Udimet 710 and IN-738, Vols. 1 and 2

GS-6441 Final Report (RP2775-1); Vol. 1, $25; Vol. 2, $25
Contractor: Rockwell International
EPRI Project Managers: J. Allen, R. Viswanathan

Laboratory Coal Ash Corrosion Tests

GS-6449 Topical Report (RP1403-19); $32.50
Contractor: Foster Wheeler Development Corp.
EPRI Project Manager: W. Bakker

Fuel Oil Utilization 1988 Workshop: Proceedings
GS-6459 Proceedings (RP2778-8); $47.50
Contractor: Energy Systems Associates
EPRI Project Manager: W. Rovesti

Corrosion Inhibitors for SO_2 Scrubber Outlet Ducts
GS-6464 Final Report (RP1871-10); $40
Contractor: LaQue Center for Corrosion Technology, Inc.
EPRI Project Manager: B. Syrett

Structure and Reactivity of a Subbituminous Coal
GS-6473 Final Report (RP8003-1); $25
Contractor: Purdue University
EPRI Project Manager: S. Yunker

NUCLEAR POWER

BWR Hydrogen Water Chemistry Guidelines: 1987 Revision
NP-4947-SR Special Report (RPT303-8); $32.50
EPRI Project Manager: R. Jones

An Independent Spent-Fuel Storage Installation at Surry Station: Design and Operation
NP-6032 Interim Report (RP2406-4); $32.50
Contractors: Virginia Power; Bechtel Power Corp.
EPRI Project Manager: R. Lambert

Surveillance of Instrumentation Channels at Nuclear Power Plants: Volume 2, An Approach to Classifying Problems and Solutions
NP-6067 Final Report (RP2906-2); $25
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Nondestructive Evaluation (NDE) Research Progress in 1988: Proceedings From the Ninth Annual EPRI NDE Information Meeting
NP-6075-SR Special Report; $47.50
EPRI Project Manager: M. Behravesh

Evaluation of Discrepancies in Assembly Cross-Section Generator Codes, Vols. 1 and 2
NP-6147 Final Report (RP2803-2); Vol.1, $25; Vol. 2, $32.50
Contractor: Utility Resource Associates
EPRI Project Manager: R. Breen

A Feature-Based Eddy-Current Imaging System for Personal Computers
NP-6167 Final Report (RP1570-2); $25
Contractor: J. A. Jones Applied Research Co.
EPRI Project Manager: G. Dau

PWR Steam Generator Examination Guidelines: Revision 2
NP-6201 Final Report (RPS404-8); $47.50
EPRI Project Manager: C.Welty

Dresden Unit 2 Hydrogen Water Chemistry: Chemical Surveillance, Oxide-Film Characterization, and Recontamination During Cycle 10
NP-6278-M Final Report (RP1930-7); $25
Contractor: GE Nuclear Energy
EPRI Project Manager: C. Wood

Guidelines for Quality Records in Electronic Media for Nuclear Facilities (NCIG-10)
NP-6295 Final Report (RPQ101-11); $25
Contractor: Vanguard Technologies, Inc.
EPRI Project Manager: W. Bilanin

Ductile Fracture Handbook: Volume 1, Circumferential Throughwall Cracks
NP-6301-D Final Report (RP1757-69); $110
Contractor: Novetech Corp.
EPRI Project Managers: D. Norris, J. Gilman

Guidelines for Threaded-Fastener Application in Nuclear Power Plants
NP-6316 Final Report (RP2859-9); $32.50
Contractor: Looram Engineering, Inc.
EPRI Project Manager: B. Brooks

Natural Circulation Experiments for PWR Degraded Core Accidents
NP-6324-D Final Report (RP2177-5); $100,000
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: B. Sehgal

Performance Assessment of Advanced Engineering Workstations for Fuel Management Applications
NP-6331 Final Report (RP2614-8); $40
Contractor: North Carolina State University
EPRI Project Managers: R. Breen, O. Ozer

The Influence of Fuel-Cycle Duration on Nuclear Unit Performance: An Update
NP-6333 Final Report (RP2490-3); $25
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EPRI Project Manager: F. Gelhaus

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NP-6340 Final Report (RP2814-4); $25
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EPRI Project Manager: J. Lang

Qualification of PWR Steam Generator Chemical Cleaning for Indian Point-2
NP-6356-M Final Report (RPS403-5); $32.50
Contractors: Westinghouse Electric Corp.; Pacific Nuclear Services
EPRI Project Manager: C. Williams

Proceedings: 1986 Workshop on Advanced High-Strength Materials
NP-6363 Proceedings (RP2181-4); $70
Contractor: Stone & Webster Engineering Corp.
EPRI Project Manager: J. Nelson

Review of the United Kingdom PWR Primary-Circuit-Chemistry Program, Progress Report No. 1
NP-6368 Interim Report (RP2493-5); $25
Contractor: Central Electricity Generating Board
EPRI Project Manager: C. Wood

Effects of Decontamination and Surface Treatments on IGSCC of Reactor Materials
NP-6374-D Final Report (RPT304-1); $6300
Contractor: General Electric Co.
EPRI Project Manager: H. Ocken

Evaluation of Potential Benefit of Transportable Storage Casks
NP-6375 Final Report (RP2717-8); $32.50
Contractor: Nuclear Assurance Corp.
EPRI Project Manager: R. Lambert

Guidelines for the Design and Operation of Makeup Water Treatment Systems
NP-6377-M Final Report (RPS306-19); $25
Contractors: Sargent & Lundy; Balazs Analytical Laboratory
EPRI Project Manager: C. Welty

Expert Training Systems to Enhance Plant Operations Decision Making
NP-6379 Final Report (RP2614-23); $25
Contractor: General Physics Corp.
EPRI Project Managers: B. Sun, D. Cain

Modeling Hydrogen Water Chemistry for BWRs
NP-6386 Final Report (RP2816-2); $100
Contractor: GE Nuclear Energy
EPRI Project Manager: C. Wood

Estimates of Zircaloy Integrity During Dry Storage of Spent Nuclear Fuel
NP-6387 Final Report (RP2062-9); $32.50
Contractors: Stanford University; Atomic Energy of Canada, Ltd.
EPRI Project Managers: R. Lambert, R. Williams

Proceedings: Engineering Characterization of Small-Magnitude Earthquakes
NP-6389 Proceedings (RP2556-25); $47.50
Contractor: Jack R. Benjamin and Associates, Inc.
EPRI Project Manager: J. Stepp

Robots to Support Radioactive Waste Activities: Task Analysis, Conceptual Design, and Commercial Evaluation
NP-6390 Interim Report (RP2232-13); $25
Contractor: Pentek, Inc.
EPRI Project Manager: F. Gelhaus

Microstructure and Stress Corrosion Resistance of Alloys X-750, 718, and A-286 in LWRs
NP-6392-M Final Report (RP2181-1); $25
Contractor: Babcock & Wilcox Co.
EPRI Project Manager: J. Nelson

Feature-Enhanced-Imaging Field Trials: Peach Bottom Unit 3, Phase 2
NP-6394 Interim Report (RP1570-2); $40
Contractor: J. A. Jones Applied Research Co.
EPRI Project Manager: G. Dau

Handling of Multiassembly Sealed Baskets Between Reactor Storage and a Remote Handling Facility
NP-6409 Final Report (RP2717-7); $32.50
Contractor: Sierra Nuclear Corp.
EPRI Project Manager: R. Lambert

The Plant Expert System (PLEXSYS) Development Environment: System Description and User's Manual, Version 2
NP-6410 Final Report (RP2582-3); $32.50
Contractor: IntelliCorp
EPRI Project Managers: D. Cain, B. Sun

Control of Nitrogen-16 in BWR Main Steam Lines Under Hydrogen Water Chemistry Conditions

NP-6424-M Final Report (RP1930-7); $25
Contractor: GE Nuclear Energy
EPRI Project Manager: C. Wood

Design Considerations for On-Site Spent-Fuel Transfer Systems

NP-6425 Final Report (RP2813-14); $25
Contractor: S. Levy Inc.
EPRI Project Manager: R. Lambert

Application of the Reactor Analysis Support Package LWR Set-Point Analysis Guidelines

NP-6432 Final Report (RP1761-1); $55
Contractor: S. Levy Inc.
EPRI Project Manager: L. Agee

A Simplified Piping Support System With Seismic Limit Stops

NP-6442 Interim Report (RP2349-1); $40
Contractor: Robert L. Cloud Associates, Inc.
EPRI Project Manager: Y. Tang

Improved Criteria for Snubber Functional Testing

NP-6443 Final Report (RP964-11); $25
Contractor: Sargent & Lundy
EPRI Project Manager: Y. Tang

Proceedings: 1988 EPRI Radwaste Workshop

NP-6453 Proceedings (RP2414-16); $32.50
EPRI Project Manager: P. Robinson

NOREM Wear-Resistant, Iron-Based Hard-Facing Alloys

NP-6466-M Final Report (RP1935-5); $25
Contractor: AMAX
EPRI Project Manager: H. Ocken

UTILITY PLANNING

Assessing Supply and Demand Uncertainties

P-6369 Final Report (RP2345-63); $25
Contractor: Strategic Decisions Group
EPRI Project Manager: T. Talbert

MIDAS Case Studies

P-6385 Final Report (RP2317-1); $32.50
Contractor: Temple, Barker & Sloane, Inc.
EPRI Project Manager: H. Chao

New Computer Software

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FORECASTMASTERPLUS: Short-Term Forecasting Package

Version 1.0 (IBM PC)
Contractor: Business Forecast Systems
EPRI Project Manager: Ray Squitieri

INPOSSM: Interactive Addition to POSSM and MCPOSSM

Version 2.0 (IBM PC); EN-6213
Contractor: Resource Planning Corp.
EPRI Project Manager: Victor Niemeyer

LIFEX: Component Life Estimation: LWR Structural Materials Degradation Mechanisms

Version 1.0 (IBM PC); NP-5461
Contractor: Structural Integrity Associates Inc.
EPRI Project Manager: Jeff Byron

LOADSYN: Load Modeling for Power Flow and Transient Stability Computer Studies

Version B-002 (IBM, VAX); EL-5003
Contractor: General Electric Co.
EPRI Project Manager: Mark Lauby

QuickTANKS: Storage Tank Risk Management

Version 1.0 (IBM PC)
Contractor: Decision Focus Inc.
EPRI Project Manager: Victor Niemeyer

RECOMOD: Refrigeration Compressor Capacity Modulation Economics Analysis

Version 1A (IBM PC)
Contractor: Applied Energy Systems Inc.
EPRI Project Manager: Paul Meagher

RODEC: Residential On-Peak Demand Charges

Version 1.1 (IBM PC)
Contractor: Utility Customer Interface
EPRI Project Manager: William Smith

CALENDAR

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

SEPTEMBER

25–28
Petroleum Contaminated Soils
Amherst, Massachusetts
Contact: Mary McLearn, (415) 855-2487

26–28
Conference: Heat Rate Improvement
Knoxville, Tennessee
Contact: Robert Leyse, (415) 855-2995

26–28
Power Quality Training for Utilities
St. Louis, Missouri
Contact: Marek Samotyj, (415) 855-2980

27–29
Applying Structural Research Results
Haslet, Texas
Contact: Paul Lyons, (817) 439-5900

OCTOBER

1
Bulk Transmission System Adequacy Assessment
Atlanta, Georgia
Contact: Neal Balu, (415) 855-2834

3–5
FASTCHEM, FOWL, and MYGRT: Codes for Modeling Solutes in Groundwater
Chicago, Illinois
Contact: Dave McIntosh, (415) 855-7918

3–6
PCB Seminar
San Diego, California
Contact: Gil Addis, (415) 855-2286

3–6
Steam Turbine Blade Life Management
Rochester, New York
Contact: Tom McCloskey, (415) 855-2655

9
Electrical Systems Division Forum
Boston, Massachusetts
Contact: Vasu Tahiliani, (415) 855-2315

10–12
EPRI Fuel Supply Seminar
Charleston, South Carolina
Contact: Jeremy Platt, (415) 855-2628

10–12
4th Annual EPRI Conference: Municipal Solid Waste
Springfield, Massachusetts
Contact: Cindy Farrar, (415) 855-2180

12–13
Seminar: Piping Seismic Research Results With Emphasis on Snubber Reduction
Burlingame, California
Contact: Y. K. Tang, (415) 855-2473

16–19
Coal Quality Development
Pittsburgh, Pennsylvania
Contact: Clark Harrison, (412) 479-3505

17–19
On-Line Coal Analysis Applications
Pittsburgh, Pennsylvania
Contact: David O'Connor, (415) 855-8970

17–20
Transmission Line Foundations
Palo Alto, California
Contact: Vito Longo, (415) 855-2287

26–27
Fuel Cell Workshop
Orlando, Florida
Contact: Rocky Goldstein, (415) 855-2171

30–November 2
Technologies for Generating Electricity in the 21st Century
San Francisco, California
Contact: Sy Alpert, (415) 855-2512

NOVEMBER

1–2
1989 Fuel Oil Utilization Workshop
Tampa, Florida
Contact: William Rovesti, (415) 855-2519

8–9
Seminar: Impacts of CFC Restrictions on Electric Utilities
Cambridge, Massachusetts
Contact: Tania Jemelian, (415) 855-2810

8–10
Conference: Geomagnetically Induced Currents
San Francisco, California
Contact: Yolanda Gale, (415) 855-2636

13–15
Conference: Marketing Electric Vans
Teaneck, New Jersey
Contact: Jim Janasik, (415) 855-2486

13–17
Battery Contractors Conference
Washington, D.C.
Contact: Glenn Cook, (415) 855-2797

14–16
Conference: Plant Maintenance Technology
Houston, Texas
Contact: John Tsou, (415) 855-2220, or Dave Broske, (415) 855-8968

28–December 1
Expo and Seminar: Meeting Customer Needs With Heat Pumps
Atlanta, Georgia
Contact: Mort Blatt, (415) 855-2457

FEBRUARY

21–23
EPRI Food Service Symposium
New Orleans, Louisiana
Contact: Karl Johnson, (415) 855-2183

MARCH

6–9
International Symposium: Performance Improvement, Retrofitting, and Repowering Fossil Fuel Power Plants
Washington, D.C.
Contact: Gary Poe, (415) 855-8969

20–23
EPRI-EPA Symposium: Transfer and Utilization of Particulate Control Technology
San Diego, California
Contact: Ramsay Chang, (415) 855-2535

JULY

29–August 3
International Conference: Indoor Air Quality and Climate
Toronto, Canada
Contact: Cary Young, (415) 855-2724

Authors and Articles


Joyner


Iveson


Balu


Jeffress

CFCs: The Challenge of Doing Without (page 4) was written by Taylor Moore, senior feature writer, in cooperation with **Powell Joyner** of EPRI's Customer Systems Division.

Joyner is the technical manager for advanced projects in the Residential Program. He came to EPRI in 1985 after 17 years with the Trane Co., where he was vice president for research on HVAC systems and industrial fume incineration. From 1963 to 1968 he worked for Allis-Chalmers, successively in fuel cell and related research and as director of research planning and evaluation. Still earlier he held scientific and management posts at Honeywell and Callery Chemical Co. Joyner graduated in physics from Centenary College; he has a PhD in physical chemistry from the University of Iowa. ■

Taking the Measure of Transmission Flows (page 14) was written by Taylor Moore, the *Journal*'s senior feature writer, in consultation with two technical managers in EPRI's Electrical Systems Division.

Bob Iveson is involved with studies of electrical phenomena in nature and in utility networks. A staff technical adviser since early 1988, he formerly managed the Power System Planning and Operations Program. Iveson came to EPRI in 1980 after 20 years with New York State Electric & Gas Corp. His work there included nine years as supervisor of transmission planning for the New York Power Pool. Iveson earned BS and MS degrees in electrical engineering at Rensselaer Polytechnic Institute and Syracuse University, respectively.

Neal Balu, who succeeded Iveson as program manager in 1988, came to EPRI as a project manager in 1979. He had worked for seven years in the planning department of Southern Company Services, where he headed the system dynamics section. Earlier, he spent four years on the faculty of the Indian Institute of Technology in Bombay. After coming to North America, Balu earned three graduate degrees in electrical engineering, including a PhD at the University of Alabama, and an MBA at Santa Clara. ■

Victoria Tschinkel: Enthusiasm for the Environment (page 20) follows the career of an environmental manager, first to leadership of a Florida state agency, then to a specialized consultancy in a Tallahassee law office—and also to membership on EPRI's Advisory Council. Tschinkel's observations are all about environmental needs—the grass roots protective actions for which we all have responsibility, and the leadership moves that are most importantly a matter of positive expectations. Feature editor Ralph Whitaker wrote the article after interviewing Tschinkel. ■

Shining Promise for Infrared Paint Curing (page 26) was written by Ralph Whitaker, feature editor, with technical guidance from **Bob Jeffress** of EPRI's Customer Systems Division.

Jeffress, a senior project manager in the Industrial Program, is particularly responsible for R&D toward the application of electrotechnologies in materials production and fabrication. He came to EPRI in 1986 after 13 years with the American Iron and Steel Institute, including five as its director of technology. He earlier worked for 10 years at Armco Steel, managing developments related to many aspects of steelmaking and process control. Jeffress has a BS in metallurgical engineering from Purdue. ■

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