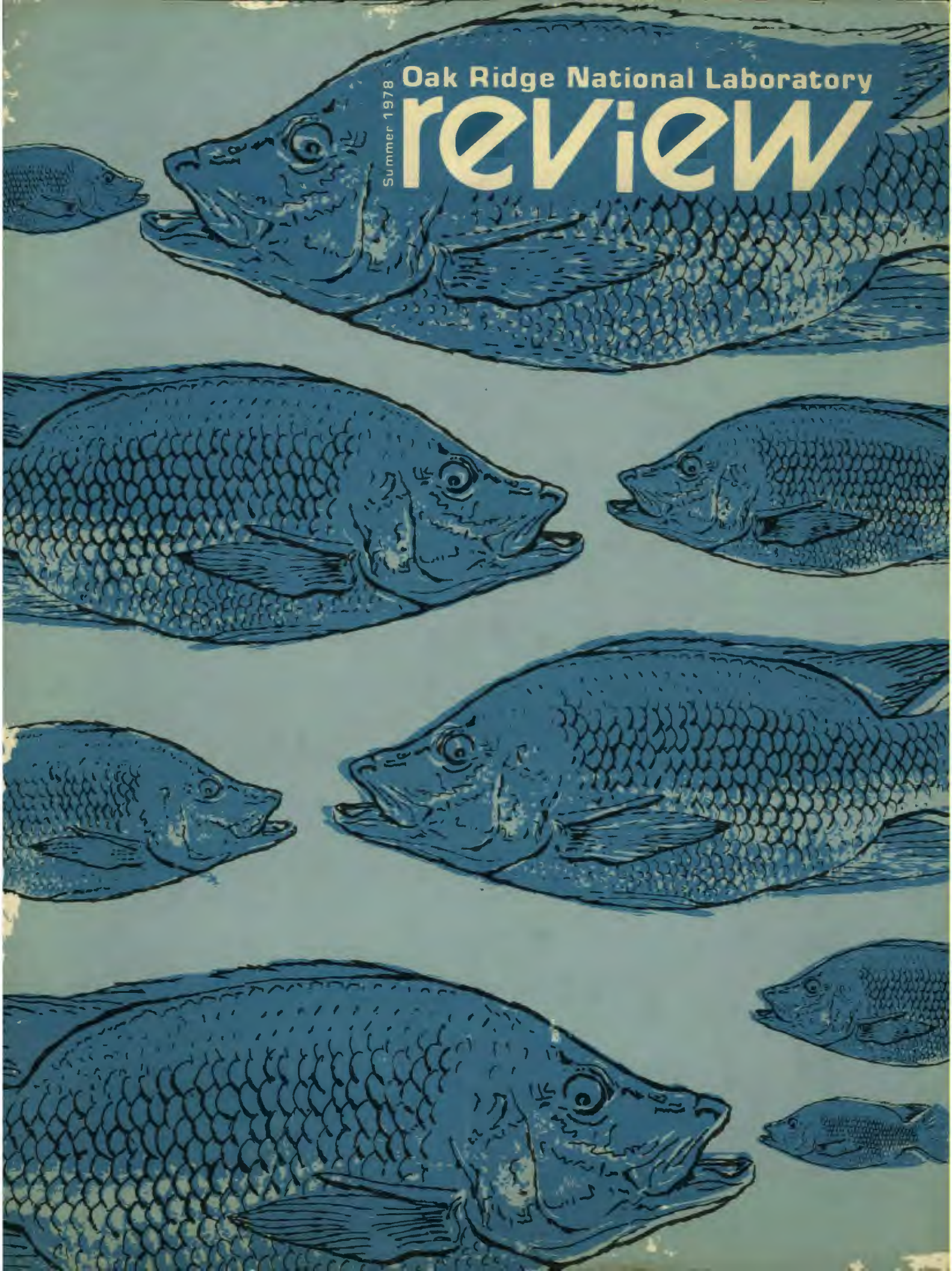
Summer 1978

Oak Ridge National Laboratory

review



THE COVER: *Tilapia* is a genus of food fishes originating in Africa, but found today on every continent that has subtropical waters. Since it apparently thrives on several things the civilized world throws away, a way to cultivate it for American commercialization is being sought at ORNL's wet lab. See Sam Suffern's account on page 30.

Oak Ridge National Laboratory

review

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OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION · FOR THE DEPARTMENT OF ENERGY

editorial

WELCOME TO THE WINNER'S CIRCLE

At the 25th International Technical Communication Conference in Dallas last spring, the Fall 1977 issue of the ORNL *Review* won first place ("Distinguished Technical Communication") in its category.

It's heady business, being a winner. Everyone should experience it at least once. It straightens the spine, fills the lungs, and strengthens the shoulders. It doesn't hurt the resume any either. Any competition is ennobled by its entrants, and the ITCC has some toppers: Hewlett Packard, Shell Development Company, IBM, National Bureau of Standards, and Eastman Kodak, among others—the names are largely in the visible range of the spectrum. So being picked first in such a company is highly gratifying to the staff of the *Review:* Clark, Krause, Lyon, and Zucker.

Most of all, it should be gratifying to the staff of the Laboratory, inasmuch as this publication reflects the quality of the work performed here. To everyone who contributes to the magazine go acknowledgments of our indebtedness. This may be an appropriate time to list some of the goals the *Review* aspires to, in the hope of enlisting more members of the Laboratory staff to work with us to attain them. Our internal distribution includes all of the ORNL employees who want to be on the mailing list, about 6000. For this group of readers, we want to offer a window on those corners of the Laboratory that are not in everyone's line of vision. We want to convey some of the pride we feel in the Laboratory as a leading world research institution. We want to highlight research activities that are intriguing, or internationally recognized, or obviously fun to do, or credited with making an immediate contribution to human well-being.

Our external distribution is made up of names of people who have personally requested that the *Review* be sent to them regularly. They include science writers, libraries and staff members of other national laboratories and universities, our supporters in Washington, and miscellaneous friends and admirers of the Laboratory in every state in the Union as well as in 39 foreign countries. To this extent, the *Review* serves as a showcase for the Laboratory staff and its research.

All this is to say that we are keen to work with anyone who is willing to have his work described in the *Review.* Although the magazine has writers who are happy to put it down on paper, much of its flavor derives from the variety of styles displayed in researcher-written articles.

Now that we have a recognized winner on our hands, we hope for a new high in readability and quality through even greater participation from the Laboratory scientific and technical staff.—*BL*

One of the newer members of the Laboratory staff is Merl Baker, who came here in 1977 from Missouri to become coordinator of the newly created Energy Conservation Program. At the time of this appointment, Baker was special assistant to the president of the University of Missouri's statewide system. Before he had that position, he served as chancellor of the University of Missouri at Rolla from 1964 through 1973. A native of Cadiz, Kentucky, with a Ph.D. from Purdue University, he was executive director of the Kentucky Research Foundation as well as professor of mechanical engineering at the University of Kentucky (where he earned his bachelor's degree) for ten years. In 1963, Baker joined the Missouri School of Mines and Metallurgy as Dean of Faculties, becoming chancellor a year later when the school was transformed into the University of Missouri at Rolla. His special research area is energy conversion. As coordinator, Baker is responsible for setting long-range goals for ORNL in energy conservation research, planning the program, and reviewing and monitoring the work of the program, which involves the efforts of six ORNL divisions and numerous subcontractors.

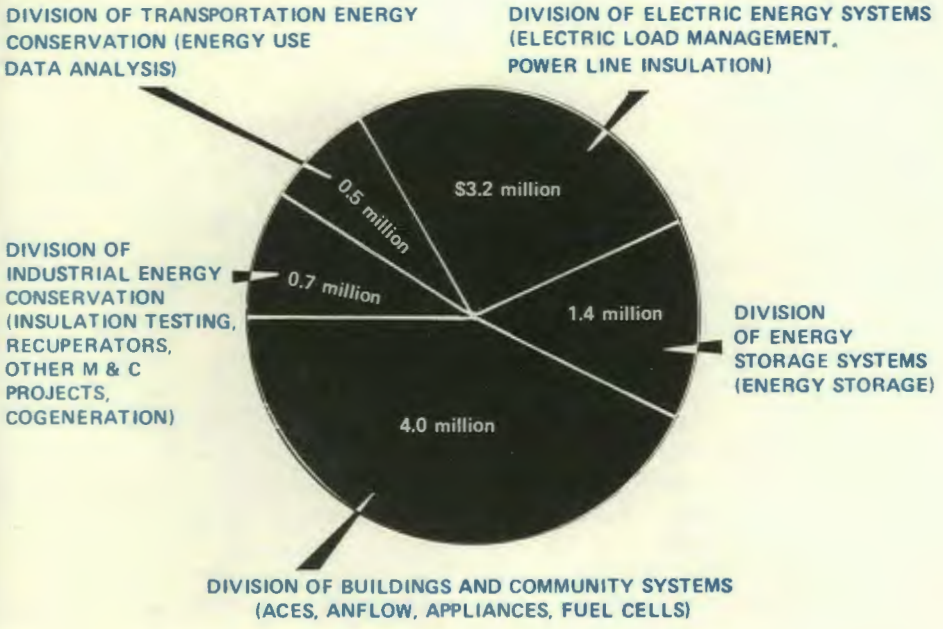
How to Save Energy:

By CAROLYN KRAUSE

SOME TIME in the 1990s somewhere in the United States, the city of Encon bills itself as the model energy conservation town. Its electricity comes from coal-fired and nuclear-fired cogeneration power plants. These plants also provide process steam for local clusters of industries, and hot water piped into the town for space heating of commercial buildings. Low-grade waste heat from industries and power plants is used to warm fish ponds and greenhouses. Industries use pipe insulation and recuperators to cut fuel consumption. The power lines run underground in pipes containing a special insulating gas to permit extremely high voltages, thus minimizing resistive losses. The local ANFLOW sewage treatment plant not only requires no power-hungry aerators to operate but even produces methane, a usable fuel. The local airport terminal is cooled in summer with winter-chilled water that has been stored in an aquifer for three months.

The city's newer houses in outlying districts have solar panels and ACES installations—underground insulated tanks of water from which heat pumps efficiently extract heat to warm building air and water, resulting in the gradual formation of ice that provides cooling in the summer and minimizes the use of the air conditioner's compressor. Some houses are built almost completely underground

How $9.8 million of DOE funds were apportioned to the Laboratory's energy conservation projects for FY 1978 is shown in this chart. ORNL conservation projects are listed parenthetically under the DOE division from whence their funding comes.



The imaginary city of Encon could easily become a reality in the 1990s because of our dwindling supplies of natural gas and oil. The city would embody many of the energy-conserving ideas of the 1970s that are being pursued at Oak Ridge National Laboratory by Union Carbide Corporation's Nuclear Division and its subcontractors with whom it is working. The goal of these schemes is more efficient and reduced consumption of oil and gas and better use of the waste heat discharged by power plants, industry—and even household appliances.

Energy conservation, in other words, means both using less energy by burning less fuel, and using more energy, by employing the heat we now throw away.

ORNL Counts Some Ways

to take advantage of the earth's natural insulation, whereas other houses have incorporated in their walls and ceilings special phase-change materials that absorb heat from the sun and release it for space heating during the colder times of day. Many homeowners and commercial outfits use dedicated heat pumps instead of resistance coils for their hot water tanks; others use the reject heat from the building's central air conditioning system to provide hot water—the so-called integrated appliance concept. Most buildings have remote-control devices on their electric meters that on a signal from a computer turn off water heaters during peak-load periods. In exchange for granting the local power company this kind of control, its customers are given lower electric rates.

The Energy Conservation Program at ORNL embraces work in six divisions: Energy, Engineering Technology, Environmental Sciences, Chemical Technology, Health and Safety Research, and Metals and Ceramics. In addition, supporting R&D is provided by Biology, Chemistry, Instrumentation and Controls, and Computer Sciences Divisions. Merl Baker, coordinator of the program, says, "My concept of energy conservation is to consider it in three components. For the near term, we need validated data bases so that designers, institutional managers, public officials, manufacturers, and consumers can make energy-saving decisions. In the intermediate term, we need to apply existing technology to achieve energy-saving machines, processes, and systems. For the long term, we need to do basic research and advanced engineering to improve these machines, processes, and systems."

The program's funding comes almost entirely from the Department of Energy, and much of the work is subcontracted to enable industry to perform energy-system development work, with technical assistance from universities, private research institutions, and national laboratories. UCC-ND has been given responsibility by DOE for planning R&D activities, awarding subcontracts, maintaining fiscal and technical control of subcontracts, and assisting in the transfer of developed technologies for demonstration and eventual commercialization.

As Roger Carlsmith, head of the Energy Conservation Section of the Energy Division, puts it, "Increasingly, ORNL is getting into management of R&D conducted by industry. With the research performed in the place where the results can be marketed, transfer of the new technology to the consumer is speedier. Our role is to provide technical expertise, to guide the research, and to see that it is done most effectively."

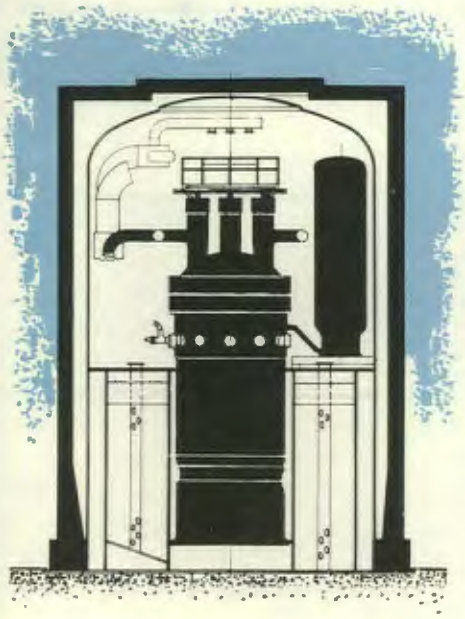
Cogeneration

"Cogeneration" is the name given to the production of electricity with its associated flow of useful heat. One concept being studied at ORNL at the initiation of Truman Anderson is the use of reject heat from coal-fired or nuclear power plants to provide process steam to a group of industries. [See "The Reactor As a Source of Industrial Energy," Anderson and Michel, Fall '73 *Review.*] Power plants used for cogeneration are energy conserving because they may waste as little as 5 to 10% of their reject heat, whereas equivalent plants producing electricity often throw away 65% of their energy in once-through cooling systems or cooling towers. Furthermore, cogenerating plants could make industrial steam, which represents 17% of the nation's primary energy use and 40% of the industrial sector's primary energy use. If coal-fired and nuclear power plants were used to provide steam for back-pressure turbines that drive electrical generators, compressors, or other mechanical devices, and if they were used to provide the low-temperature turbine exhaust steam for industrial processes, the fuel now required to meet these needs would be reduced by 20 to 35%.

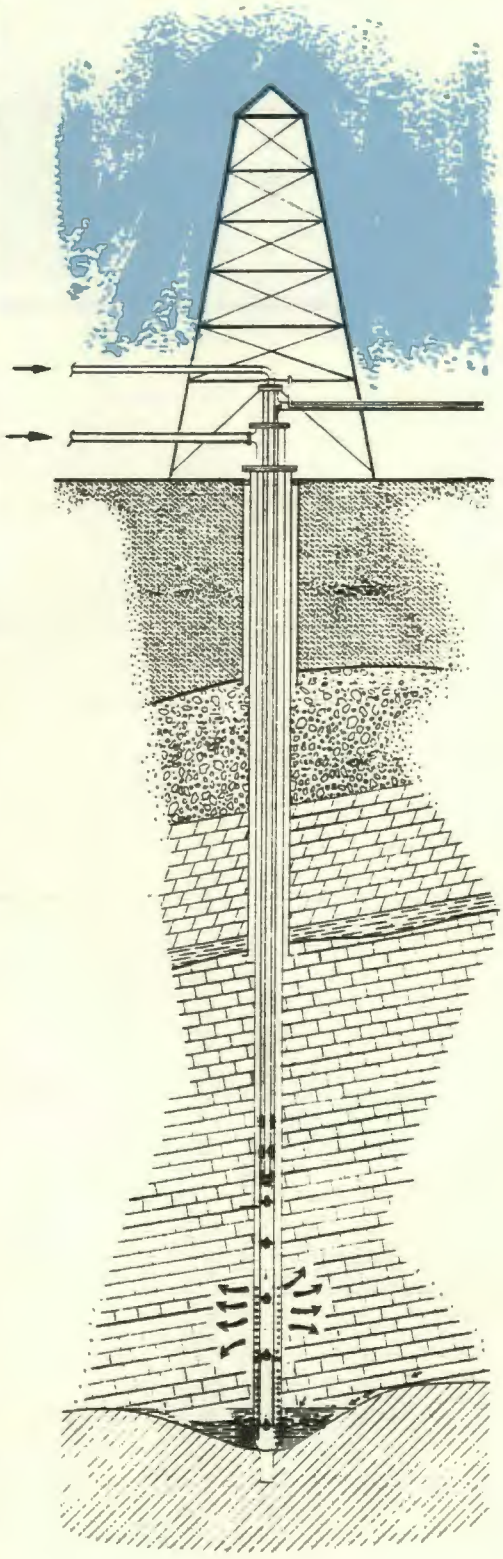
Because the thermal energy from a large plant would exceed the needs of a single chemical plant or petroleum refinery, one focus of ORNL studies is to match a large power plant to a cluster of industries. Dunlap Scott of the Engineering Technology Division is managing a DOE-sponsored study with Gulf States Utilities to examine specific sites where a coal or nuclear plant could be used to generate electricity and process steam for a group of industries.

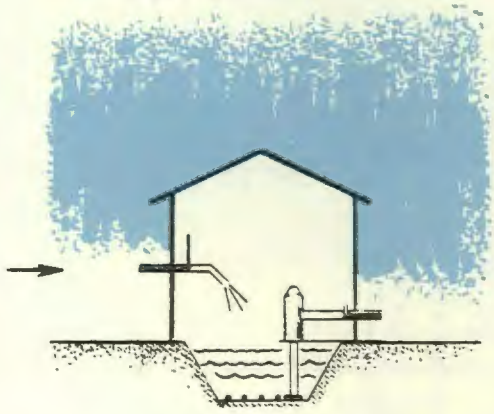
Otto Klepper, also of Engineering Technology, is providing technical assistance and program management of DOE-sponsored work with three industries to weigh the costs of using a coal-fired plant or small nuclear plant to supply individual industries' electrical and thermal energy needs. The nuclear plant under consideration is the Consolidated Nuclear Steam Generator (CNSG), a 365-MWt light-water reactor developed by Babcock & Wilcox (B&W) and modeled after earlier B&W reactors used for ship propulsion. As its name implies, this small-sized nuclear plant has the unique feature of having the steam generator located inside rather than outside the reactor pressure vessel. Because of economy of scale, the cost per kilowatt is higher for smaller nuclear plants; but B&W is hopeful that this economic penalty might be overcome in part by marketing a small standardized plant suitable for series production.

With assistance from Millard Myers and Len Fuller of ORNL, Klepper has completed a report on the possible application of small reactors to supply process heat. A further report, prepared by B&W under subcontract to UCC-ND, evaluates industrial reactor feasibility at a West Texas sulfur mine owned by the Duval Corporation. This report



In this proposed scheme for the Duval Corporation's sulfur mine in Texas, a small light-water reactor would be used for cogenerating electricity and process heat for sulfur extraction. The process heat is used to make hot water that is injected deep into the ground to recover sulfur. Electricity is used to power the drilling tower and the equipment that pumps air and hot water into the ground and molten sulfur up to the top via pipes. Below is the molten-sulfur collection system.





examines the way in which a 12-MWe CNSG in addition to producing electricity could use the balance of its steam for sulfur extraction. Currently, Duval Corporation (a subsidiary of Pennzoil) is using natural gas for its boilers. Klepper and W. G. Sullivan of The University of Tennessee have found capital and operating costs of coal and nuclear plants to be competitive. However, Klepper acknowledged in the report that industry is hesitant to use nuclear power due to uncertainties in licensing, impacts of intervenors, and project schedules. Coal-fired plants also pose problems for industry because federal air quality standards necessitate purchases of low-sulfur coal and expensive pollution abatement equipment.

Klepper is also studying the possibilities of cogeneration for Pittsburgh Plate Glass Industries in Lake Charles, Louisiana, and for the Du Pont plant in Victoria, Texas. He says that an oil-fired superheater is needed so that the temperature of the new steam supply will match that of the gas-fired boilers that are to be replaced.

An example of community cogeneration is the concept of the Modular Integrated Utility System (MIUS), which has been studied at ORNL for seven years under the auspices of the U.S. Department of Housing and Urban Development. The concept includes a community-dedicated electrical generating station so situated that its waste heat can be effectively used for space heating or cooling, for water heating, for making potable water, and in manufacturing operations. The community's liquid and solid wastes would be delivered to the MIUS power plant for processing and disposal. A MIUS could be sized to accommodate several hundred or a few thousand multifamily dwelling units, nearby single-family housing, and associated commercial facilities.

A study by Bill Mixon, Bill Boegly, and others, of the consequences of using hypothetical oil or gas-fired MIUS installations

A view of underground-transmission piping for a district heating system in Sweden.

for new multifamily housing in Dallas, Miami, Minneapolis, Philadelphia, and San Diego gave these results:

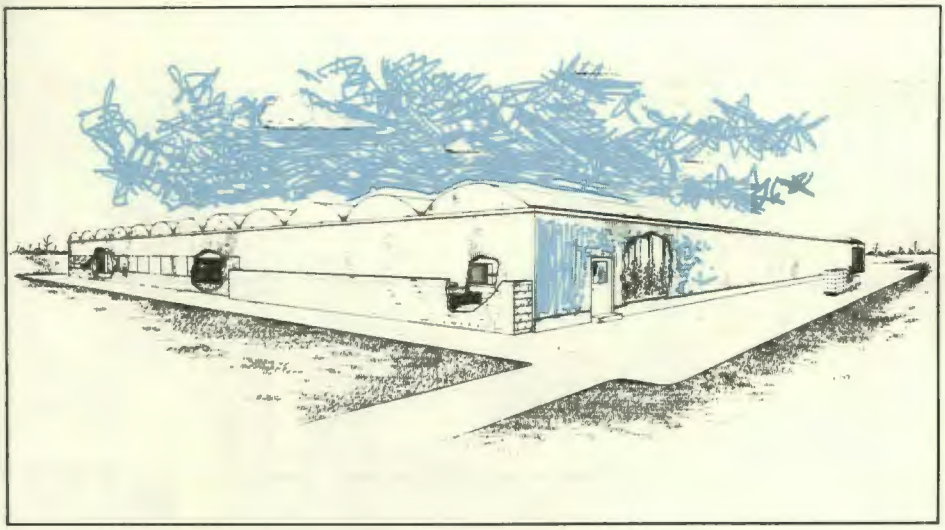
- On the average, 30% less primary fuel would be consumed if MIUS power plants were used instead of conventional utility systems.
- On a total cost basis, MIUS installations using currently available technology are competitive with the cost of providing conventional utilities to residential developments.
- MIUS installations have fewer environmental impacts than do conventional systems, largely because MIUS reject heat is utilized.

District Heating

Reject heat from power plants can also be used for district heating, employing a century-old concept of piping hot water or steam for residential and commercial space and water heating. Although district heating has been extensively used in Russia, Sweden, and other European countries, it has had limited use in the United States. It was first tried here in Lockport, New York, in 1877; subsequent systems in the early part of this century utilized the exhaust steam from small, noncondensing steam-electric plants to heat buildings in nearby business districts. But the growth of the U.S. district heating industry was curtailed by two developments: the introduction of large power plants that were remotely located, and the availability of abundant supplies of cheap oil and natural gas for space heating. Now that these supplies are no longer abundant, the district heating concept looks attractive once again to Americans. Besides conserving dwindling fuel supplies, district heating also makes efficient use of waste heat, thereby reducing thermal pollution and offering the potential of making a cogeneration plant 80% efficient with a small sacrifice in electrical output.

In 1976, Irv Spiewak began an investigation of long-distance transport of thermal energy from nuclear power plants. When DOE initiated a program to determine the technical and economic feasibility of supplying thermal energy from nuclear power plants, ORNL was selected to coordinate the effort, which includes participation by federal and state agencies as well as by private industry. Part of the program is a site-specific study to evaluate cogeneration in combination with district heating for a large city.

The focus of the district heating study is the Minneapolis–St. Paul area, selected partly because it meets technical criteria, such as a high number of degree days, a high-density population, a large potential heat load, and the feasibility of considering both coal and nuclear power as potential fuels. However, DOE/UCC-ND chose the Twin Cities primarily due to the enthusiastic commitment of local agencies and firms to take part in the study. They include Northern States Power Company, the Minnesota Energy Agency, Minnegasco, the University of Minnesota, the Minnesota Pollution Control Agency, and the Metropolitan Council. UCC-ND/ORNL selected the subcontractor, AB Atomenergi, a research laboratory in Sweden, to conduct the Twin Cities study. Begun in April 1977, and scheduled for completion this summer, the bilateral effort indicates so far that the economics are favorable for large piping systems in the residential and commercial zones, with a newly developed plastic piping suggested for areas of low heat-load densities, such as housing developments outside the city. AB Atomenergi has developed a scenario for a 15-year period in which the existing power plants are eventually supplemented by new cogeneration plants that pipe hot water into a network which



Artist's conception of the greenhouse to be built near TVA's Browns Ferry Nuclear Power Plant in Alabama. The greenhouse, which will be warmed by waste heat from the nuclear facility, was designed by the University of Arizona under a contract managed by ORNL.

would connect outlying residential areas with the denser urban areas. It is possible to pipe hot water 40 miles without more than a drop of 1°C.

What is ORNL's role in this project? The Engineering Technology Division is working with the other participants in addressing a number of questions: What is the estimated cost of adapting existing downtown buildings so they can draw their energy from district heating? Because nuclear power has no adverse effect on air quality as do coal plants, what is the possibility of obtaining regulatory approval for siting nuclear plants nearer to cities to facilitate district heating applications? ORNL also proposes to analyze the institutional issues posed by district heating, including such barriers as financing, rates, tax policy, organizational structure, hook-up policy, franchising, environmental regulation, and construction impacts.

The ORNL Energy Division is also conducting an air quality modeling study to predict the effect of a district heating scheme on the Twin Cities' air quality. One stack used in the production of electricity and thermal energy would replace emissions from many low-level stacks. A number of Swedish cities that have a large fraction (60 to 95%) of heat supplied by district heating also have greatly reduced levels of sulfur dioxide concentrations in comparison with towns which utilize many small oil-fired boilers. The effect district heating can have on air quality depends to a large extent on the type of fuel being replaced in each individual unit.

Waste Heat Utilization

The combination of district heating and cogeneration is now frequently referred to as a thermal energy grid. A recent preliminary study by Mitchell Olszewski of the Engineering Technology Division indicates that the concept is both economically and technically feasible. Olszewski found that thermal grid heating would be most competitive economically in areas of high heat-load density and high fuel costs, such as multifamily-residence areas. The economics of thermal grid heat are also attractive for industry. Other conclusions of the ORNL study include the following:

- Hot water transmission lines (pipes about 4 ft in diam) appear practical for distances up to 40 miles, although steam lines may be acceptable for distances of 10 miles or less.
- For residential and commercial users, thermal grid heat systems would be more economically competitive when installed in a new building complex than when retrofitted in an existing oil or electrical system. The cost difference between new and retrofitted systems for industry appears small.
- It appears uneconomical to supply single-family residences with thermal grid heat.

The ORNL report recommends that future studies focus on the use of thermal grid heat for an industrial area and a residential/commercial area (such as an apartment building and shopping mall complex) in order to obtain detailed information on load patterns and economic feasibility.

Olszewski has also studied the possible uses for low-grade reject heat, that is, those effluent waters which exit at a temperature range of 30 to 50°C. For several years, ORNL has participated with the Tennessee Valley Authority in examining the use of waste heat from an electric boiler to warm an experimental greenhouse at Muscle Shoals, Alabama. The greenhouse uses honeycomb-shaped evaporative pads (studied at ORNL) through which the hot

The Muscle Shoals greenhouse uses evaporative pads through which circulate hot water from an electric boiler designed to simulate the waste heat rejected from a power plant. ORNL participated in the design of the greenhouse and conducted performance tests for the evaporative pad material.

water passes to warm a stream of air used to heat the greenhouse. At Browns Ferry Nuclear Plant, TVA is building a small greenhouse designed by the University of Arizona under contract to ORNL. Because most greenhouses today are heated by propane, use of reject heat could help greatly to conserve this expensive, dwindling fuel. ("Every Btu of waste heat used displaces 1.3 Btu of fossil fuel," says Olszewski.)

Although greenhouses offer a promising use for waste heat, Olszewski has concluded in his study that the best option for reject heat utilization is aquaculture. He has determined that 75 1000-MW power plants could supply enough heat to domestic ponds and tanks to raise all the fish needed to meet U.S. demands for "block" fish—minced fish flesh frozen into blocks and used for fish sticks. The energy conservation potential of waste heat aquaculture is considerable because raising fish domestically would replace ocean fishing, resulting in large savings in oil use. Says Olszewski: "Our studies indicate that, on the average, fish from our waste heat aquaculture operation require only about 25 to 50% of the total energy input required for ocean caught fish." Formidable problems have been encountered in using waste heat aquaculture to raise such prized species as lobsters, trout, and shrimp, but an ORNL researcher has identified a species of pan fish which responds well to waste heat aquaculture. Sam Suffern of the Environmental Sciences Division (who discusses this elsewhere in this issue) has been cultivating a delectable fish called tilapia, which feeds on water hyacinth, algae, and duckweed. Olszewski is working on designing a waste heat aquaculture system for tilapia; his studies include a cost analysis, calculation of the net energy balance, and selection of the best heat exchangers. Collaborating with him on the engineering design work are Holly Bigelow and John Wilson.

In his study on waste heat utilization, Olszewski concluded that the best options, in this order, would be (1) aquaculture, (2) swine- and chicken-house heating, (3) greenhouses, (4) intensive aquaculture, and (5) undersoil heating for agriculture. He puts undersoil heating in last place because his computations show that crop increases would not compensate for piping expenses.

Waste Treatment

At the Oak Ridge East Waste Treatment Plant, there is an ORNL-designed pilot plant that not only produces energy but saves it in the process of treating about 5000 gallons of sewage per day. Called ANFLOW (shorthand for "anaerobic upflow packed-bed bioreactor"), the system has demonstrated that it can produce more methane and use less energy for treating sewage than do conventional methods. The ANFLOW pilot plant consists of a packed tubular column (10 ft high and 5 ft in diameter) containing one-celled organisms that consume and digest liquid wastes in an oxygen-free environment. The pilot plant was based on earlier bench-scale research performed by Alicia Compere and Bill Griffith, now with the Chemistry Division. Richard Genung, of the Chemical Technology Division, is the principal investigator in charge of the pilot plant.

A recent comparison of an ANFLOW system with conventional plants of similar size revealed that ANFLOW consumes about one-tenth of the energy required at an activated-sludge treatment plant and about one-sixth of the energy needed by a trickling-filter system. The savings are due largely to the fact

Cucumbers, as well as tomatoes, have been grown successfully at TVA's experimental greenhouse at Muscle Shoals, Alabama.

An Annual Cycle Energy System ice bin has been installed for testing at the Westinghouse HOMELAB near Pittsburgh, Pennsylvania.

that ANFLOW uses anaerobic organisms, meaning that less sludge is produced and energy-consuming aerators are not required.

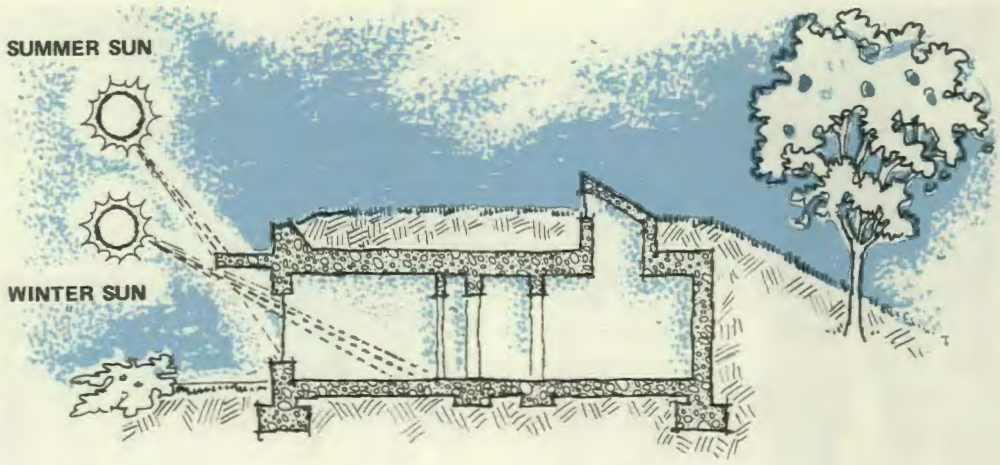
ANFLOW is one of a class of advanced bioreactors which the Chemical Technology Division is developing for residential and industrial waste treatment. Whereas ANFLOW is a fixed-bed bioreactor, another type is the fluidized-bed system in which the packing materials, such as coal particles to which the organisms adhere, move freely about in conical or cylindrical columns while liquid wastes to be treated are pumped in from below. Such a system has been successfully used at ORNL to remove toxic phenols from coal-liquefaction waste streams.

Chuck Scott, associate director of the Chemical Technology Division, says that bioreactors offer potential not only for cleaning up industrial waste streams but also for using less energy than conventional processes and for utilizing waste process heat. Says Scott: "Since biological systems will operate faster at moderately higher temperatures, low-grade heat can enhance the efficiency of bioreactors," ORNL researchers are also investigating the possibility that ANFLOW and other bioreactor systems can tolerate toxic-metal pollutants better than can conventional treatment systems due to shorter residence times of waste streams in bioreactors.

Scott is optimistic that fluidized-bed bioreactors using alumina and sand particles as packing could have applications in the wood products and dairy industries not only for removing pollutants but also for producing valuable chemicals. For example, organisms in a bioreactor can convert waste cellulose from the wood industry and lactic acid from dairy wastes into glucose, which can be sold to chemical industries as a foodstock or as a chemical intermediary for making other compounds. ORNL has developed several proposals to test bioreactors for industrial waste treatment and for coupling them with sources of waste heat, such as TVA's generating plants.

Annual Cycle Energy System

During the coldest weeks last winter, the ACES demonstration house on Alcoa Highway south of Knoxville consumed only about 35% as much electricity as did a control house at the same location (3 kW vs 8 to 10 kW). Besides saving energy (and thus money), ACES also eliminated the sharp demand peaks exhibited by the control house, which has electrical resistance heating. The peak demand for the ACES house was about 4 kW compared with 14 kW for the control house; such reduction in peak demand is quite impressive to utilities that are subject to erratic demands on their generating capacity. Because ACES draws energy from a constant-temperature tank of water, the system's efficiency is independent of outdoor weather conditions. The efficiency of an



This is architect Hanna Shapira's conception of an underground house complete with skylight and a view from the south side of the outdoors. The semiburied structure would be enveloped by insulating and water-proofing materials.

air-to-air heat pump, on the other hand, decreases as the outdoor temperature decreases until at lower temperatures it is no higher than that of straight electrical resistance heating. For heating purposes. ACES is about three times as efficient as resistance heating; for cooling from stored ice, it is about six times as efficient as an ordinary electric air conditioner. ORNL researchers Leonard Abbatiello, John Moyers, and Allen Holman are keeping a watchful eye on the ACES house as the end of its first full year of operation approaches.

On the national ACES scene, ORNL's Bob Minturn is monitoring a number of DOE projects across the country, and is also trying to keep abreast of the more than a dozen private sector ACES demonstrations, residential and commercial, which have resulted from the ORNL/DOE development of the ACES concept.

Underground Buildings

One idea for significantly reducing energy losses from buildings is to construct them underground. The advantage of such subsurface construction is that the earth provides good, low-cost insulation from the vagaries of the weather, although underground structures are subject to an increased likelihood of water damage as well as to the psychological barrier of seeming to have less access to outdoor scenery and sunshine. Almost all designs to date, however, include courtyards, skylights, and windows, which have the effect of bringing the outdoors in. These considerations and those of other innovative design possibilities were discussed at a national workshop held in mid-May in Texas for builders, architects, and other interested people. The workshop was arranged by the University of Texas and supported by DOE's Innovative Structures Program, managed by Bob Minturn at ORNL. As recommended at the workshop, a number of demonstration underground buildings are being planned for the near future. At ORNL, Connie Chester and associates are doing a preliminary design for an underground house for possible construction in the Oak Ridge area.

Heat Pumps

The more efficient a heat pump is, the less electricity is required to operate it. Fred Creswick and Albert Domingorena of the Energy Division have been testing different models of air-to-air heat pumps to determine how much they vary in overall and in component efficiencies. They have completed testing on one model and have found that the results agree closely with the manufacturer's claims regarding overall performance. They are making recommendations in a DOE report on how manufacturers could improve heat pump performance by such means as installing larger heat exchangers and more efficient compressors. Creswick is also providing technical assistance on UCC-ND subcontracts with designers and manufacturers of heat pumps.

Appliance Efficiency

A large opportunity for energy conservation exists in the area of residential and commercial appliances, which account for 12% of national energy consumption and 40% of total energy use in the residential and commercial sectors. ORNL has assumed management of research, development, and demonstration programs for DOE to make marketable appliances more energy efficient. Virgil Haynes, DOE program manager for residential and commercial appliances (in the Energy Division), says that UCC-ND is subcontracting work to manufacturers to develop more energy-

efficient appliances, such as water heaters, refrigerators, and room air conditioners.

"ORNL/DOE is sponsoring projects to stimulate the improvement of appliances and to speed up the introduction of improved, marketable products," Haynes say . "By assisting manufacturers in their research, we expect to have them participate on a cost-sharing basis to improve the chances that new energy-efficient appliances will reach the marketplace."

Subcontractors have been, or are being, selected to redesign the following products for increased efficiency:

- Motor-compressor units for use in refrigerator-freezers and room air conditioners.
- Electric water heaters. Electric water heaters conventionally use resistance heating, so efforts are being made toward coupling a dedicated heat pump with a water tank. Foster Miller Associates is working on a reverse Brayton air-cycle heat pump to heat water, and Energy Utilization Systems, Inc., is adapting state-of-the-art Rankine-cycle heat pump technology systems for both retrofit and new applications.
- Refrigerator-freezers (subcontract awarded to Arthur D. Little, Inc., with Amana Refrigeration, Inc., as a sub-subcontractor).
- Gas-fired water heaters.

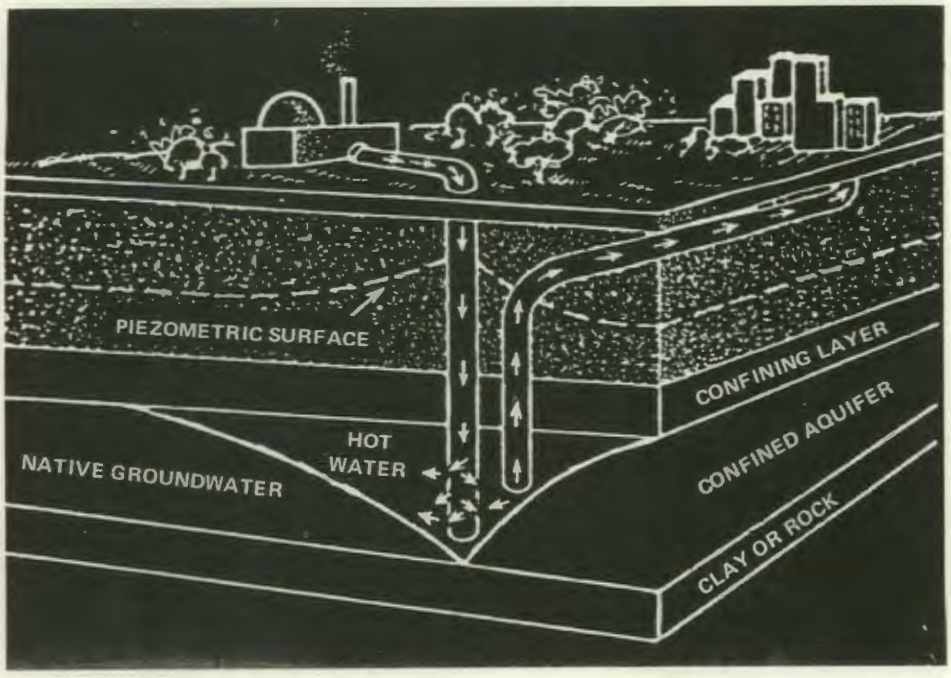
Under contract to DOE, A. D. Little has completed a study of opportunities to save energy by combining appliances. The principle behind this concept of "integrated appliances" is that energy rejected by one appliance can be used as input to another. Three combinations of appliances identified as the best candidates for DOE demonstration projects are (1) central air conditioners with water heaters. (2) furnaces with water heaters, and (3) commercial range-hood heat recovery with water heaters.

Other subcontracts awarded by UCC-ND for ORNL collaboration went to Thermo Electron Corporation to analyze opportunities for energy conservation in commercial appliances; to A. D. Little to determine if there are any energy-storage concepts that might be used to significantly improve energy efficiency of consumer appliances; to Enviro-Management and Research, Inc., to develop brochures and bulletins for promoting energy-saving consumer products and better energy-use patterns; and to Purdue University to hold a conference related to home appliance energy conservation.

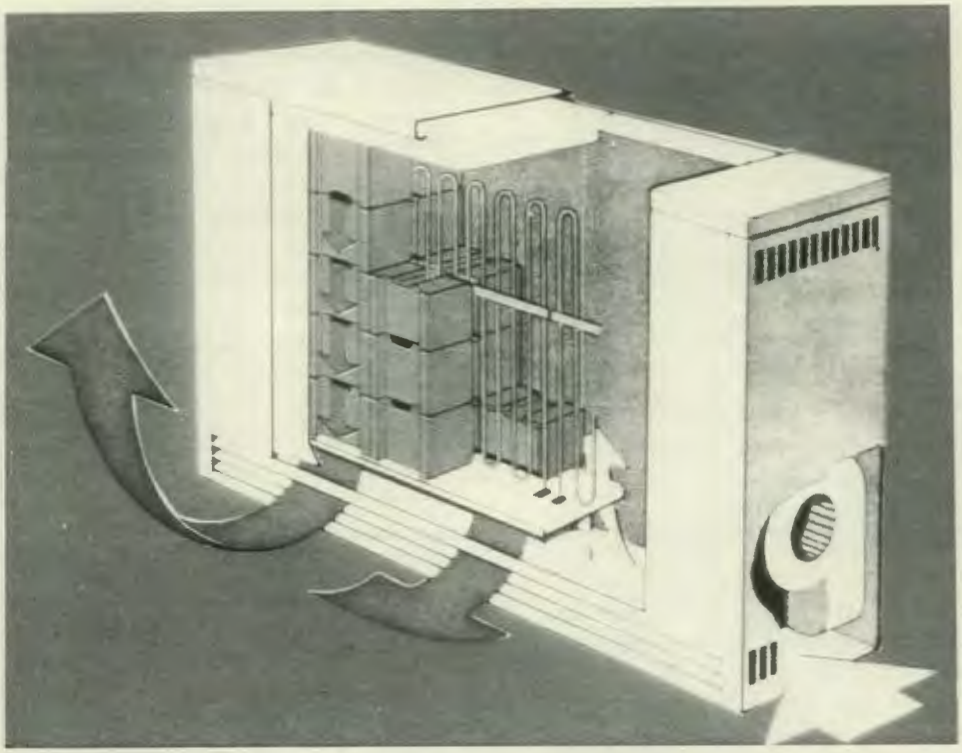
The modus operandi of Haynes and colleagues is to evaluate solicited and unsolicited proposals, including those received in response to Requests for Proposals (RFP) that are inserted as ads in *Commerce Business Daily*. Subcontracts are awarded on the basis of national energy impact, public and private costs, cost sharing, economic benefits, technical feasibility, and commercialization potential.

Energy Storage

One of the newer areas of energy conservation research is thermal energy storage (TES)—reserving heat (or cold) produced at one time for a later time when it is needed. Under this concept, heat deriving from a number of sources that are poorly utilized currently could be stored and used



Aquifers are subsurface geologic structures (e.g., gravel-filled regions between two essentially impervious clay layers) containing water that has percolated downward from the surface. In this illustration, the normal aquifer water would be displaced by pumping in hot water from a power plant or industry; after storage until the winter season, this hot water would be pumped out of the aquifer for use in heating building complexes (district heating).



This cutaway view of a room-sized ceramic brick furnace shows the bricks which are heated by off-peak electricity. During peak-load periods on cold days, the furnace's blower is activated, sending air past the hot bricks to provide space heating, as in this living room in a Vermont home (right). The ceramic brick heater is one type of energy storage device that Central Vermont Public Service has found useful in managing electrical loads. Larger units for central installations are also available.

on demand for space heating and cooling to save fuel and to reduce peak loads—an attractive idea from the standpoint of both the utilities and the consumers.

ORNL is managing one of the three parts of a program of national scope within DOE's Division of Energy Storage Systems to develop the requisite TES technologies. Called the Low-Temperature Thermal Energy Storage Program (LTTES), its goals are defined by program manager Herb Hoffman (Engineering Technology Division) as "advancing the application of such alternative energy sources as solar energy, industrial waste heat, off-peak electricity, and ultimately utility-cogenerated heat in the residential, commercial, industrial, and agricultural use sectors through sensible and/or latent heat storage at temperatures generally below 250°C." The upper temperature limit was arbitrarily chosen to be sure that absorption air conditioning fell within the program domain. (The other parts of the national program are High-Temperature Thermal Energy Storage run by NASA-Lewis Research Center and Thermochemical Thermal Energy Storage managed by Sandia Laboratories, Livermore.)

LTTES is an advanced technology development program, so in the sensible heat area, LTTES looks to concepts that lie beyond the realm of such essentially commercial systems as "water in tanks" or "rock piles." Thus, seasonal storage through the use of aquifers is emphasized. An aquifer—sometimes colloquially called a slow-moving "underground river"—can be used to store hot water rejected from industrial processes and/or provided from cogeneration power plants or cold water obtained in winter for three to six months at a time. This hot or cold water could then be pumped up during the appropriate season to supply space heating or air conditioning. Under contract with ORNL, Auburn University is engaged in a field study at a power plant to determine the parameters of heat storage in a confined aquifer; and Texas A&M University is investigating, in a parallel fashion, the problems of storing winter-chilled water in an unconfined aquifer. A particularly exciting effort just under way is a study by Desert Reclamation Industries of the possibility of aquifer storage of winter-generated cold water for the summer air conditioning of the terminal buildings at J. F. Kennedy Airport in New York.

Another technology being considered for seasonal storage of solar energy utilizes the earth surrounding or beneath a dwelling as the storage medium. The particular concept being

developed by George Washington University uses a heat pipe system for the injection and recovery of heat from a water-saturated subsurface sand bed.

Systems utilizing phase transitions to store heat have long been held attractive for energy storage. Commonly, this system involves a melt/freeze process, although some solid-state transitions possess interestingly high heats of transition. (Water, for example, releases 80 cal/g as it freezes into ice; ice must correspondingly absorb 80 cal/g in melting back to water.) Nearly 30 years ago, Maria Telkes proposed Glauber's salt ($Na_2SO_4 \cdot 10H_2O$), which melts at 32°C with a latent heat of fusion of 60 cal/g for such a vehicle; this phase-change material (PCM) has been incorporated into one of the solar energy test homes built by the University of Delaware. ORNL continues to support development not only of this "older" concept but also of a number of newer intriguing ideas; for example, Monsanto Research Corporation is developing a partially cross-linked polyethylene which retains its shape in the molten state and which, with a freeze-melt transition temperature of 130°C, could be used in a packed-bed configuration to store solar energy for absorption air conditioning.

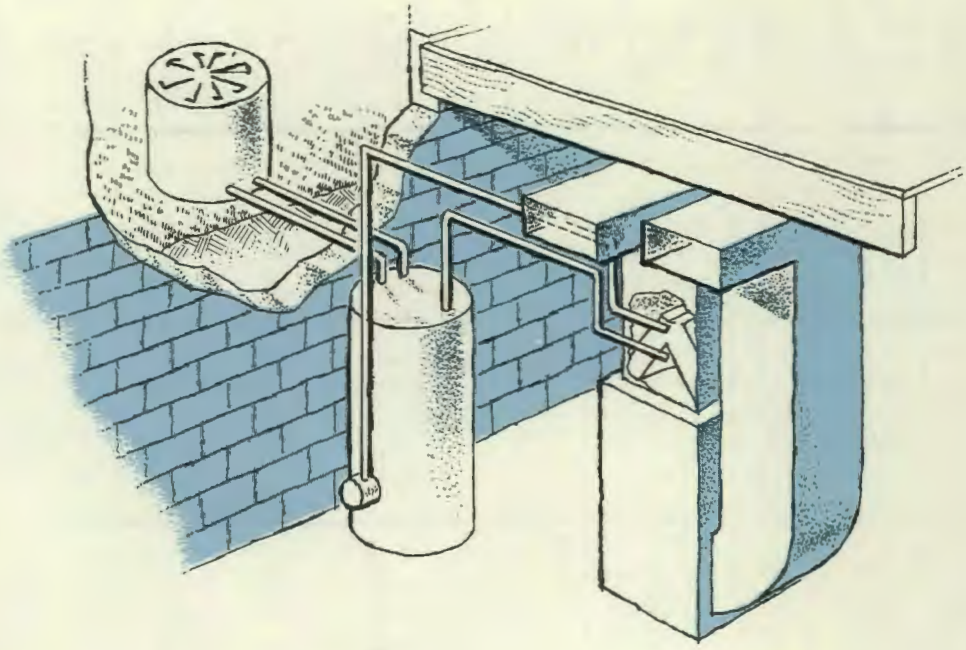
Building materials such as concrete blocks, wall panels, and ceiling tiles that are infused with PCMs (e.g., salt hydrates) could be used for diurnal storage in connection with solar or off-peak-electricity energy sources. According to Hoffman, such a latent-heat-storage mode offers "an exciting prospect for 'comfort zone' heating and cooling. Thus, room surfaces could be maintained at an appropriate constant temperature to provide for the physiological perception of comfort despite reduced air temperatures. Furthermore, building-material storage permits incorporation of the energy storage device without consuming living space." ORNL is working with Suntek Research Associates and one of our sister laboratories, Brookhaven, to develop this concept.

Here at home, ORNL researchers are supporting subcontract efforts through varied activities in the Chemistry, Computer Sciences, and Engineering Technology divisions. Among the problems being considered by ORNL scientists and engineers are crystal structures of hydrates and their nucleators (chemicals that hasten crystallization at freeze temperatures), the potential of PCMs for use in absorption air conditioning, a computational description of the PCM freeze/melt process, and a corresponding physical model to test the predictions.

Electric Load Management

For years, utilities have faced the problem of peak loads—that is, having enough power plants in operation or ready to be started up quickly to meet the needs of their customers during the hours when demand for electricity is heaviest. Since peak loads have grown annually with expanding residential and industrial developments, utilities have had to invest enormous sums of money to build large new nuclear and coal-fired plants as well as smaller gas and oil-fired peaking plants, which are expensive to operate. If all American utilities exercised load management (changing the patterns of electricity use), they would not have to build as many new power plants and consume as much fuel to meet rising energy demands; the resulting savings in energy and money by the year 1985 would be equivalent in value to 200,000 barrels of oil per day, plus a $10 to $15 billion reduction in capital needed for system expansion. Load management would also cut back on the use of peaking plants, saving on the use of increasingly costly oil and gas and stabilizing the cost of electricity. Load management could also avoid the collapse of the power system due to insufficient supply to meet demand, such as occurred last summer in New York City. For these reasons, many utilities and the Department of Energy have accorded high priority to testing and implementing load management concepts that use technological developments to avoid imposing significant changes on customers' lifestyles.

An ORNL group under Hugh Long is currently providing technical assistance to DOE's Division of Electric Energy Systems for load management programs involving thermal-energy storage and field demonstrations of communication systems for distribution automation. The group will soon provide program management and technical support to eight utilities for ten demonstrations which will assess the impact of residential thermal-energy storage systems designed to reduce peak loads. In one of these systems, for example, a ceramic brick furnace will be used for bulk storage of heat. The power is turned on during off-peak hours to heat the bricks, and air blown past the bricks during peak hours on



This is an artist's conception of a stored-cooling installation in Milwaukee, Wisconsin, in which an air conditioner produces ice during off-peak times for subsequent use on peak to provide space cooling. Wisconsin Electric Power Company has operated two of these installations for the past two years.

cold days will provide space heating. In another system, ice will be produced by the air conditioner during off-peak times for subsequent use during on-peak periods to provide space cooling. In both cases, energy is supplied by the utility at the most economical time, while the customer uses the energy at his convenience.

Data from these end-use systems will help to determine the impact of such technologies on the utility system's planning and operations. In addition, Long and his colleagues are comparing the impact of these systems to other possibilities for energy storage, such as batteries at substations and central pumped-storage plants. Today, utilities depend only on pumped-storage plants to produce hydroelectric power when peak demands are high.

Long and his group also serve as technical monitors of a DOE-funded demonstration project of the San Diego Gas and Electric Company System which involves testing two-way remote-control devices that read home meters for billing purposes. In addition, these devices are capable of interrupting electric service during peak-load periods. These transponders, which are mounted on residential and commercial electric meters, can turn off water heaters temporarily and can control space heaters or air conditioners on a signal from a central computer. In exchange for giving the utility this control over their power use by permitting the installation of these devices (manufactured by the American Science and Engineering Company under contract to DOE), several hundred San Diego customers are given preferential electric rates. This new system allows the utility to shut off power selectively to certain customers for short periods in order to achieve electric-load leveling. Similar devices, activated by radio signals or by electronic impulses sent out through telephone or power lines, are being tested in other cities (Raleigh, North Carolina; Omaha, Nebraska; and Long Island, New York) as part of a national program jointly planned and funded by DOE and the Electric Power Research Institute (EPRI). Besides monitoring the San Diego test, ORNL is also monitoring a project in which the Omaha Public Power District is testing a telephone-based system manufactured by the DARCO Telemetering Company.

In addition, Long's group manages a contract with the Power Department of the City of Burbank, California, to study the effects of controlling electric loads in local industries, including Burbank Studios and the Lockheed Aircraft Company.

Working with Long on these various projects are Mike Kuliasha, Ron Young, and Dave Eissenberg (Engineering Technology Division), Ray Adams (Instrumentation and Controls Division), and Bill McLain (Computer Sciences Division).

Power Line Insulation

Five to ten percent of the electricity transmitted along power lines in the United States is wasted through resistive losses—that is, the heat generated by resistance in the conductors is dissipated to the air. These losses, equivalent in energy to as much as a million barrels of oil daily, could be minimized by reducing the current and increasing the voltage. But there is a limit to the

A utility service man sets the initial meter reading on a remote transponder at a customer's home in Omaha, Nebraska. Upon request from the central utility office, the transponder automatically transmits meter readings from the customer's meter.

voltage that can be applied to transmission lines because the field generated from too high a voltage could cause a "breakdown" in the surrounding air, resulting in an electric discharge between the line and the ground.

One possible solution which would allow higher voltages is to place electrical cables underground in pipes that contain a gaseous dielectric more resistant to breakdown than air. This idea is attractive for aesthetic reasons also, as well as obviating the possible health hazards of high-voltage lines. The obvious disadvantage, however, is its cost.

Even so, a group under Loucas Christophorou in ORNL's Health and Safety Research Division has been studying various combinations of gases, primarily carbon-fluorine compounds so far, which could serve as more effective insulators than the conventionally used gas dielectric, sulfur hexafluoride (SF_6). The researchers have found these gases to have breakdown strengths superior to pure SF_6 in themselves, and in mixtures with nitrogen and/or other cheap and inert abundant gases, include perfluorocyclobutane (c-C_4F_8), perfluorobutene-2 (C_4F_8), perfluoro-2-butyne (C_4F_6), perfluorocyclohexene (C_6F_{10}), perfluorocyclopentene (C_5F_8), and perfluorodimethylcyclobutane (C_6F_{12}).

Breakdown is the process whereby free electrons in air or in some other gaseous medium are sufficiently energized by high-voltage fields to knock electrons loose from the grip of gas molecules. The colliding electrons and the newly freed electrons are accelerated by the field until they have enough energy to ionize other molecules and to set free more electrons; the resulting "chain reaction," or electron multiplication, produces an electric spark or discharge, much the same as lightning. To prevent such conditions, the ORNL group is in quest of *multicomponent gas mixtures* that have the ability both to slow down and to capture free electrons.

Insulation Testing

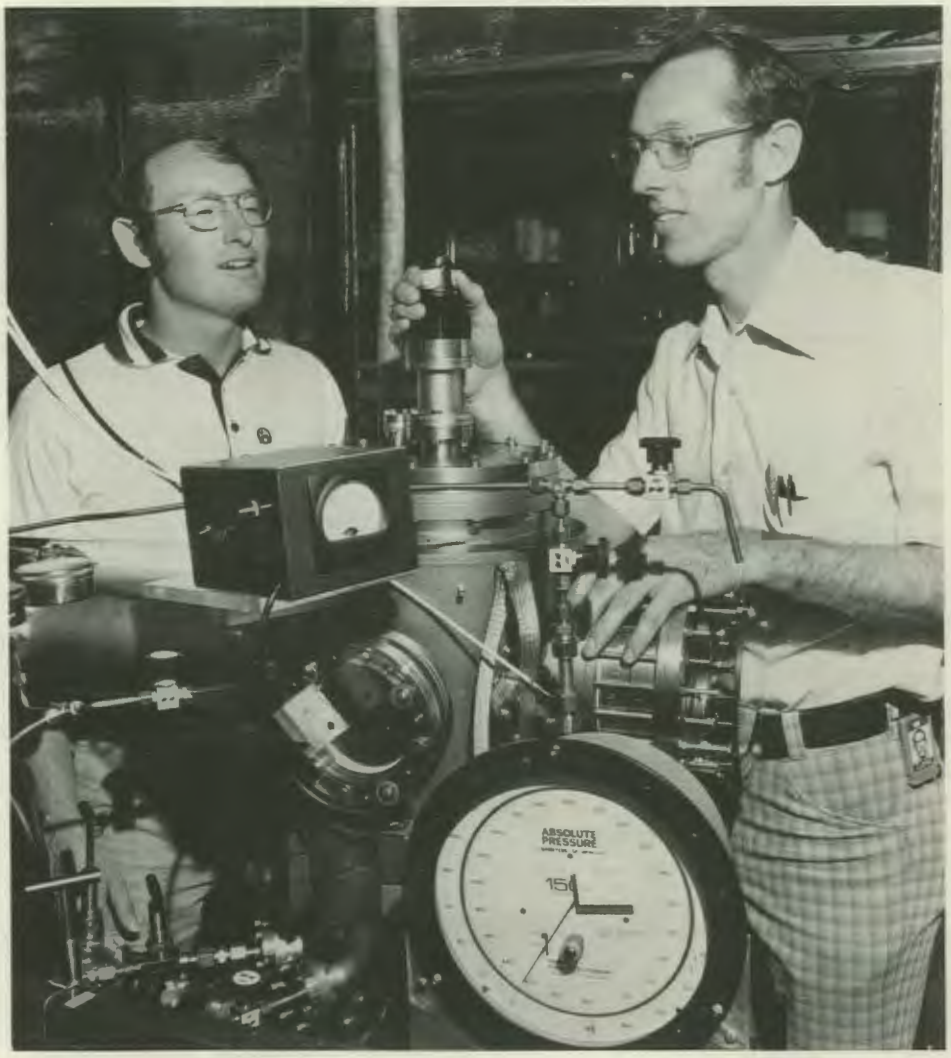
The industrial sector accounts for about 40% of the nation's energy consumption, so large opportunities exist in this area to reduce fuel usage. One way to help industry conserve energy is to evaluate accurately the resistance to heat flow of widely used thermal insulations. The availability of an inexpensive, simple method of evaluating industrial insulation could be useful in helping industries to choose the optimal type and thickness of insulation for pipes that carry high-temperature process fluids, such as steam.

Three researchers in ORNL's Metals and Ceramics Division—Stanley H. Jury, David McElroy, and J. Peyton Moore—have developed a simplified pipe insulation tester which is just as accurate as the more complex, costlier pipe tester devised to conform to specifications issued by the American Society for Testing and Materials. Moreover, the ORNL prototype is easier to adapt to various insulation forms. The ORNL "ideal tester" was conceived from a computer program (HEATING5) that simulates the steady-state temperature distribution of pipe insulation testers. The ORNL researchers built a mockup of the ideal tester, which consists simply of a resistively heated core heater made of stainless-steel-mesh screen (to minimize axial heat flow), and tested the mockup with calcium silicate pipe insulation. The results agreed reasonably well with the computer simulations and data of other pipe testers.

McElroy is principal investigator on another project to evaluate and analyze building insulation. The project's goals are to define the effective thermal resistance variation of batt insulations (fiberglass and rock wool), to provide technical assistance to DOE for program plan development, and to evaluate cellulose insulation.

Ted Lundy of the M&C Division is managing the Thermal Insulation Materials and Envelopes Systems (TIMES) Program for DOE's Division of Buildings and Community Systems. So far

Randy James (left) and Richard Mathis work at a test chamber for conducting studies of the dielectric strengths of various gases (mostly carbon-fluorine compounds) when voltages as high as 300 kV are applied.



under this program, ORNL has advised DOE in its joint planning efforts with the U.S. Department of Commerce, which have resulted in the establishment of a plan. UCC-ND has let contracts that are managed by Lundy in the areas of standard reference materials for insulation (which are sorely lacking), fire testing, and cellulose corrosion testing. Contracts are being negotiated for field studies of insulation installation, UF-foam processing, and arrangements for a Thermal Insulation Conference to be held this October, as well as insulation systems testing in walls, ceilings, and roofs. One of Lundy's goals is to guide the insulation industry in developing standardized testing procedures.

Recuperator Materials

Another way to reduce industrial fuel consumption is to use recuperators, a type of heat exchanger designed to recover heat from hot flue gases for preheating combustion air or gases that are low in energy content. A recent technology assessment by Vic Tennery and G. C. Wei of the M&C Division showed that most recuperators used in such American industries as steel and glass manufacturing are constructed of stainless steel. But greater savings in fossil fuel consumption could be attained by using materials that can withstand process exhaust gas of even higher temperatures (above 980°C). Certain ceramic materials may be superior to stainless steels as candidates for advanced recuperators due to their lower creep and better resistance to oxidation and corrosion at extremely high temperatures. Despite these advantages, Tennery and Wei have identified several "major impediments" to more serious consideration of ceramic materials for recuperator construction. These include their fabrication costs, brittleness, sensitivity to thermal-shock fracture, lack of adequate joining and repair techniques, inadequate nondestructive examination techniques, and lack of appropriate specifications for structural ceramics for use in recuperators.

Conversion to New Fuels

Shortages of natural gas have forced many industries to switch to alternative fuels to burn in their furnaces. Conversion to coal necessitates expensive rebuilding of equipment, so it was not surprising that a recent assessment by Wei and Tennery revealed a pronounced shift to fuel-oil combustion by many industries. They found that a number of industries were using residual fuel oils, which are

Isador Sauers, a University of Tennessee postdoctoral student, adjusts a time-of-flight mass spectrometer used to identify initial decomposition products of dielectric gases.

cheaper than distillate oils but which contain higher levels of impurities that are detrimental to furnace linings. The ORNL researchers' literature review and their contacts with industry elicited information about the adverse effects of residual fuel oil on the refractory and insulation linings of furnaces. This assessment led to a two-phase program in the M&C Division which consists of (1) examining failed refractories and insulations from industrial furnaces, and (2) testing ceramic materials with fuel-oil combustion at ORNL's Refractory Test Facility and then examining these materials for such deleterious effects as chemical reactions, cracking, and swelling. The objective of both approaches is to identify the attack mechanisms in hopes of devising ways to improve the service life of refractories and insulations. The development of improved refractories would undoubtedly speed up industry's shift from dwindling natural gas supplies to more abundant fuel oils.

Some of the findings of the M&C studies in the two-phase program have implications for fuel-use patterns in the near term:

- Because deterioration and corrosion of refractories take place primarily due to reactions with impurities in fossil fuels, from an operational viewpoint distillate oil is more desirable than residual oil as industrial fuel because it has a low impurity content. However, because residual fuels are cheaper, they are regarded as a prime alternate fuel in the next five years by the aluminum, ceramics, copper, glass, chemical and petrochemical, and petroleum refining industries.
- Widely used furnace linings made of fireclay brick and chrome-magnesite brick and regenerators made of periclase brick are degraded by reactions with impurities in residual oil. Vanadium in the oil attacks both types of ceramic materials. The chrome-magnesite refractories also undergo detrimental reactions due to the presence of nickel, sodium, and potassium in the residual oil.

Fuel Cells

A fuel cell is a device in which the energy released in the oxidation of a conventional fuel is continuously changed to electrical energy. Advanced fuel cells are now being developed to use synthetic and fossil fuels with atmospheric oxygen; such devices have a high conversion efficiency and are potentially superior economically to the lower efficiency steam-electric plants now in commercial service.

Bill Mixon, Gerald Pine, Jeff Christian and others in the Energy Division have examined the technical and economic feasibility of installing "fuel-cell total-energy systems" in large buildings such as apartment complexes, offices, schools, hospitals, retail stores, and hotels and motels. Such systems would provide electricity and thermal energy for space heating and for heating water, although conventional backup systems would be required to meet some heating needs. The advanced systems under consideration are phosphoric acid fuel cells (developed

Dave McElroy (left) and J. P. Moore examine a mockup of the pipe insulation tester they developed. The device, which consists simply of a resistively heated core heater made of stainless-steel mesh screen, is being used to evaluate the resistance to heat flow of calcium silicate, a thermal insulation.

by United Technologies Corporation) which burn natural gas or synthetic fuels made from coal. After looking at many different factors, including the costs of alternative energy systems in large buildings, the ORNL researchers tentatively concluded that the demand for fuel-cell total-energy systems would be highest for apartment buildings, and that most sales would be in the New York–New Jersey region. "But," says Mixon, "while the projected use of such systems through the year 2000 saves primary fuel energy, displacement of conventional coal and nuclear electrical generation results in increased gas use for such systems."

Energy Use Data Analysis

The Data Management and Analysis Group of the Energy Division plans to revise and update its *Transportation Energy Conservation Data Book,* which has become a standard reference for transportation energy planners. In addition to presenting timely statistics on the major transportation modes and energy consumption patterns, the document will contain analyses of the basic data. D. B. Shonka and D. L. Green, the principal investigators, will document and resolve data inconsistencies and idiosyncrasies and will develop techniques for measuring key data items. Analyses will be documented in a series of monographs on transportation energy conservation. The data group also provide critical reviews of other DOE-sponsored projects and respond quickly to ad hoc requests from government officials for special information. Recent reports issued by the group have influenced federal policy on gasoline rationing.

This past spring, the Energy Division issued the *Buildings Energy Use Data Book,* which

Vic Tennery (left) and Arvid Pasto discuss an ongoing test of ceramic materials with fuel-oil combustion at the Refractory Test Facility shown in the background. They will then examine the materials (such as fireclay brick) for such effects as cracking and swelling caused by reactions with impurities in oil during combustion at temperatures as high as 1370°C.

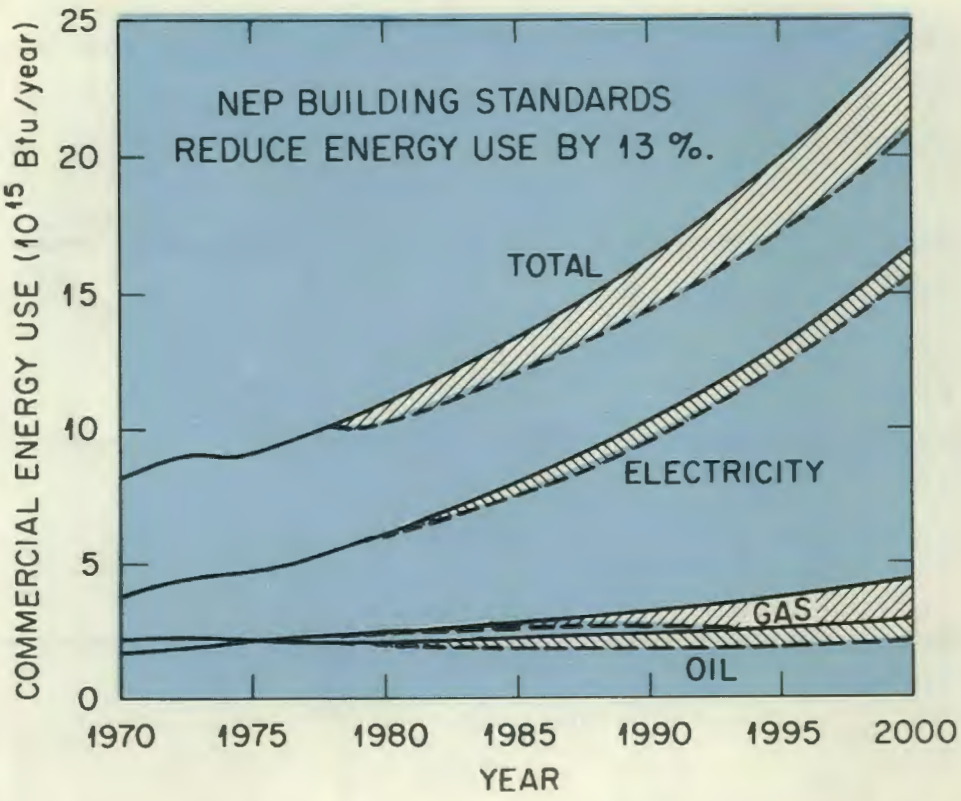
provides information on current and past energy uses in the residential and commercial sectors and which identifies areas where data are lacking or are inconsistent. Gunar Liepins and Marlene Smith, the main contributors to this document, are planning to investigate derived energy use in both sectors and to evaluate solar energy alternatives and selected energy-use simulation models and their applicability to a viable conservation program. They will also study the feasibility of analytic detection and identification of residential energy losses and the suitability of these methods for field use.

Group leader Andy Loebl and Liepins are collecting, analyzing, and reconciling data in preparation of a data book on industrial energy use. They seek to integrate conservation-program data analysis at ORNL with DOE conservation and with other federal programs dedicated to the collection and evaluation of industrial energy-use data. The researchers are examining the balancing of the energy-supply/energy-use equations, documenting the use of internally generated fuels, and analyzing selected major end-use categories such as process steam and direct heat in terms of their energy intensity as a function of end products and industrial processes.

Future Energy Demand

The Energy Division has been developing computer models to forecast the annual growth in energy demand in the residential and commercial sectors between now and the year 2000. Energy use in homes accounts for 22% of the nation's energy budget, and the commercial sector consumes about 13% of the energy used.

Eric Hirst and his colleagues have concluded that the growth in demand for energy in the residential sector will decline because of slower population growth, higher and rising fuel prices, and approaching satura-



Commercial energy use by fuel is depicted here. If the building standards proposed as part of the National Energy Plan are implemented, commercial energy use will be reduced by 13%.

tion for major household energy uses. If the energy conservation program proposed by President Carter is enacted into law, Hirst calculates that by the year 2000 American consumers will pay $29 billion in extra capital costs (insulating materials, more efficient appliances, etc.) but will pay $56 billion less in fuel bills. Also, under the Carter program, the average annual growth rate for energy demand would fall to 1.2%, in comparison with the historical annual growth rate of 3.6% from 1970 to 1975.

Using a simulation model with an equivalent level of detail, Jerry Jackson and Steve Cohn have forecast commercial energy use through the year 2000, based on current trends and on assumptions that proposed conservation policies will be implemented. They have predicted the amount of electricity, natural gas, oil, and other types of fuel that would be used for space heating, cooling, water heating, lighting, and other uses in ten different commercial-building categories. These building types are retail-wholesale outlets, finance and other office-related activities, auto repair and garage facilities, warehouse activities, educational services, public administration, health care services, religious services, hotel-motel services, and miscellaneous commercial activities.

According to Jackson, commercial energy use has grown more rapidly than residential energy use (5.1% per year vs 4% per year between 1955 and 1973). He adds: "A growing number of energy conservation programs point to a tremendous conservation potential in commercial buildings. Energy savings up to 60% have been achieved through minimum cost measures such as reduced lighting, reduced ventilation, and equipment shutdown during hours that the building is unoccupied. The high growth rate of commercial energy use, plus the tremendous conservation potential in commercial buildings, suggests a total conservation potential that may be as great as that of the residential sector, which consumes nearly twice as much energy."

Even though the commercial sector is expanding, the growth in energy demand is expected to decline since builders are now constructing more energy-efficient buildings. Economically, this trend makes good sense because the cost of conservation-related improvements is offset by the reduced capital and operating costs of the smaller equipment required to heat and cool the more efficient buildings. If fuel prices keep rising and if proposed tax incentives and standards are imposed under President Carter's National Energy Plan to make buildings, appliances, and lighting more efficient, the Jackson-Cohn model forecasts that annual growth in commercial energy use will dip from 5 to 4.3%, and that in the year 2000 the commercial sector will consume 15% less energy than it will if the National Energy Plan is not implemented.

take a number

BY V. R. R. UPPULURI

Flipping of Stacks

Imagine a restaurant with a sloppy chef and a finicky waiter. When the chef prepares pancakes, they come out in all different sizes. Before the waiter serves an order of pancakes, on his way to the table he arranges them by size, with the smallest on the top, graduating in diameter down to the largest on the bottom. He does this by grabbing several from the top and flipping them over, repeating this as many times as necessary. Note that the number flipped each time may be different, but always the top stacks are flipped. One can ask for the maximum number of flips one will ever have to use, $f(n)$, to rearrange n pancakes.

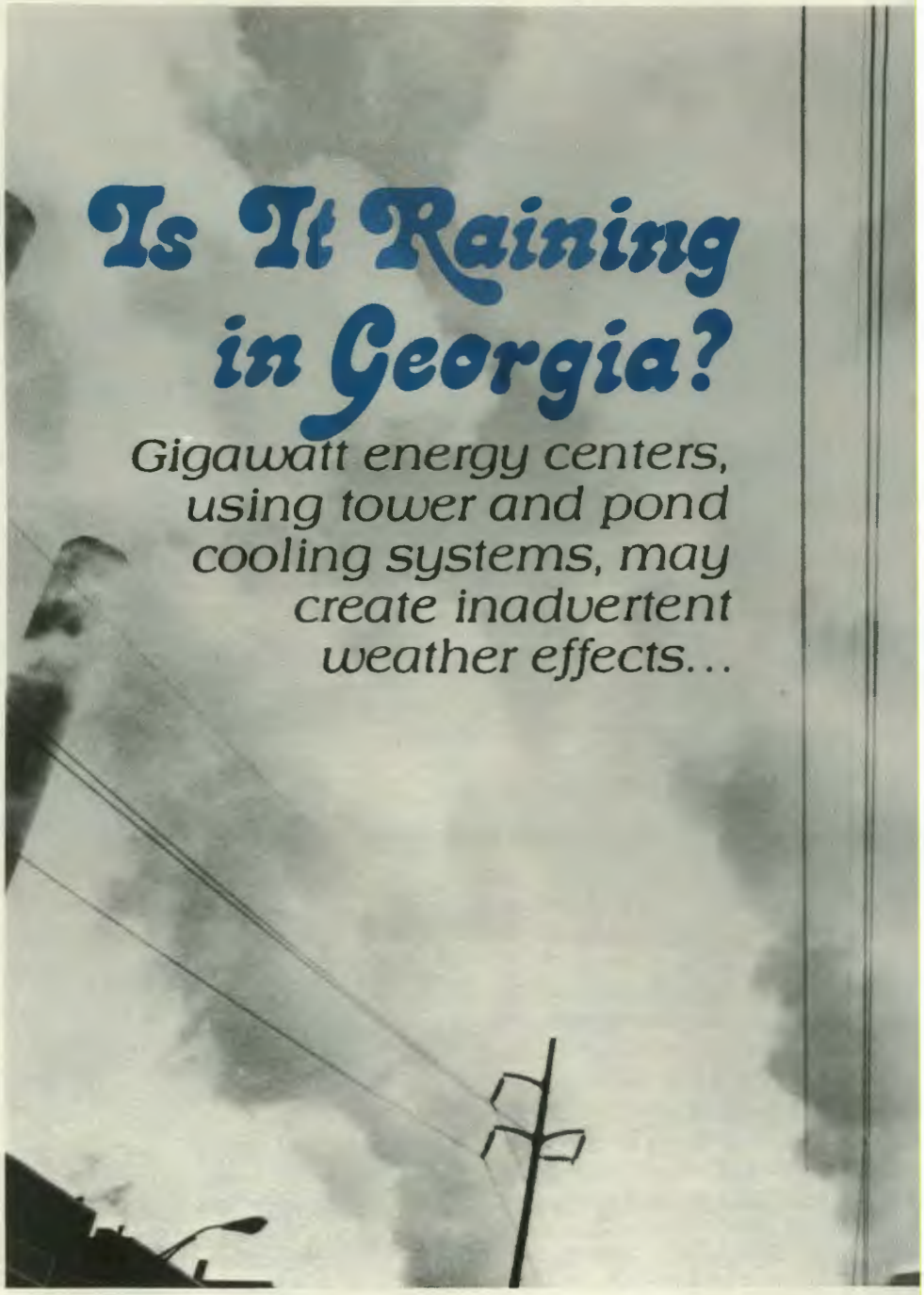
For example, suppose we have four pancakes whose sizes are denoted by 1 (smallest), 2, 3, and 4 (largest). Let them be arranged by the chef in the order 2 4 1 3 (bottom to top). One flip of the smaller stack, 4 1 3, by the waiter will change it to the order 2 3 1 4. A second flip of this whole stack gives the new order 4 1 3 2. A third flip of the smaller stack 3 2 gives the order 4 1 2 3. Finally, a fourth flip of the stack 1 2 3 gives the desired order, 4 3 2 1. For this problem, one cannot obtain the desired order in less than four flips, although there are several ways of attaining the goal.

Only the short table shown below is as far as is known to date regarding n vs $f(n)$.

n	1	2	3	4	5	6	7
$f(n)$	0	1	3	4	5	7	8

Is It Raining in Georgia?

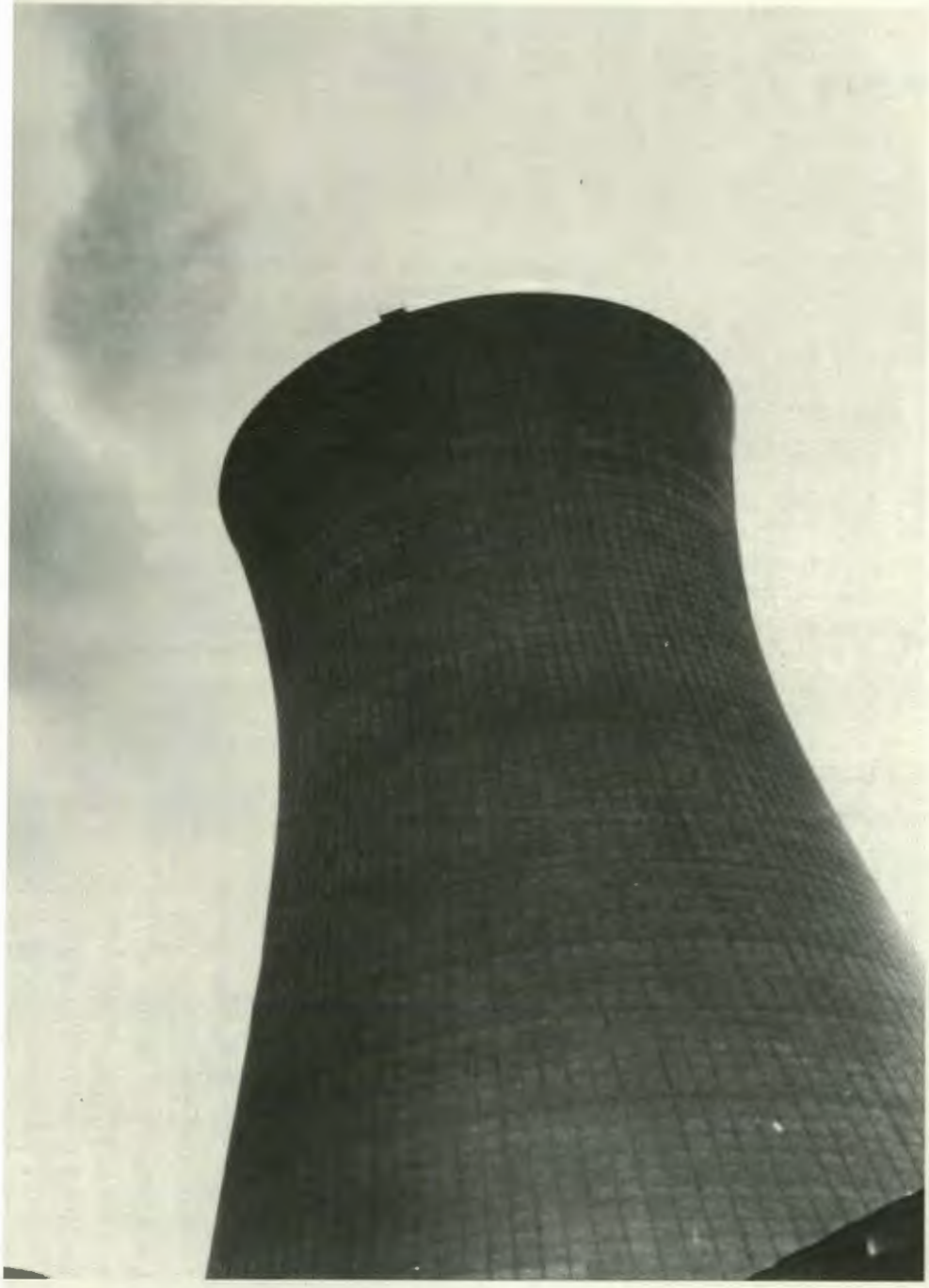
Gigawatt energy centers, using tower and pond cooling systems, may create inadvertent weather effects...



By ARISTIDES PATRINOS

Phil Hayes and I made up one of three groups that spent a couple of weeks last winter riding around rural northwest Georgia, asking people if we could set up a weather station on their land. For the most part, we were met with recognition, thanks to the extensive advance public information campaign that had been launched by Carol Grametbauer in the Nuclear Division public relations office. We had been interviewed on local radio and TV, stories had been published in local papers, and all in all about half of the people we talked to initially were aware of our program. Of course, once we had started operation, word of mouth got the news around most efficiently. We were looking for 49 sites in a 25-mile square around a power plant on which to establish rain and wind monitors. The two weeks in February that we drove Phil's blue Toyota around Georgia were just a small part of the careful and elaborate preparations that went into—and are still going into—this DOE-ORNL program.

Rain in Georgia is the subject we're investigating. The members of the Heat Transfer-Fluid Dynamics Section who were with me last winter were Bob Miller, Norbert Chen, and Rich Saylor of my group; Phil Hayes and Lincoln Jung went along to help us set up. The program, called METER—Meteorological Effects of Thermal Energy Releases—is sponsored by DOE. The program is designed to study the concept of nuclear energy centers that may be built in response to ever-increasing energy demands, and also to provide some solutions regarding siting, safeguards against nuclear proliferation, and safety. Such energy centers—agglomerations that can produce twenty times as much electricity



as currently existing plants—would use cooling systems with both towers and ponds rather than the once-through cooling systems common today. This usage would discharge heat and moisture into the atmosphere in sufficient quantities to make possible all sorts of inadvertent weather effects. Recently, the program has been expanded to include all types of energy centers (fossil, nuclear, or combinations of both) as well as existing large power plants (up to four units at a single site). The potential atmospheric effects considered include precipitation and modification (rain and snow), drift deposition, fog and icing, and shadowing, as well as triggering of severe storms and tornado enhancement.

Early work on METER at Oak Ridge has dealt with modeling of drift deposition and plume dynamics. In the past year, the emphasis has shifted to the study of possible rainfall changes caused by the cooling towers of large plants. The Bowen Electric Generating Plant of the Georgia Power Company was chosen as a test site. Bowen is a coal-fired, 3200-MWe plant with four natural-draft, evaporative cooling towers, about 40 miles northwest of Atlanta. The first of its four units began operating in October of 1971, the last in November of 1975. It is one of the largest power plants in the world and certainly is the largest to use cooling towers as the sole cooling method. Its relative proximity to Oak Ridge made it even more attractive for our study.

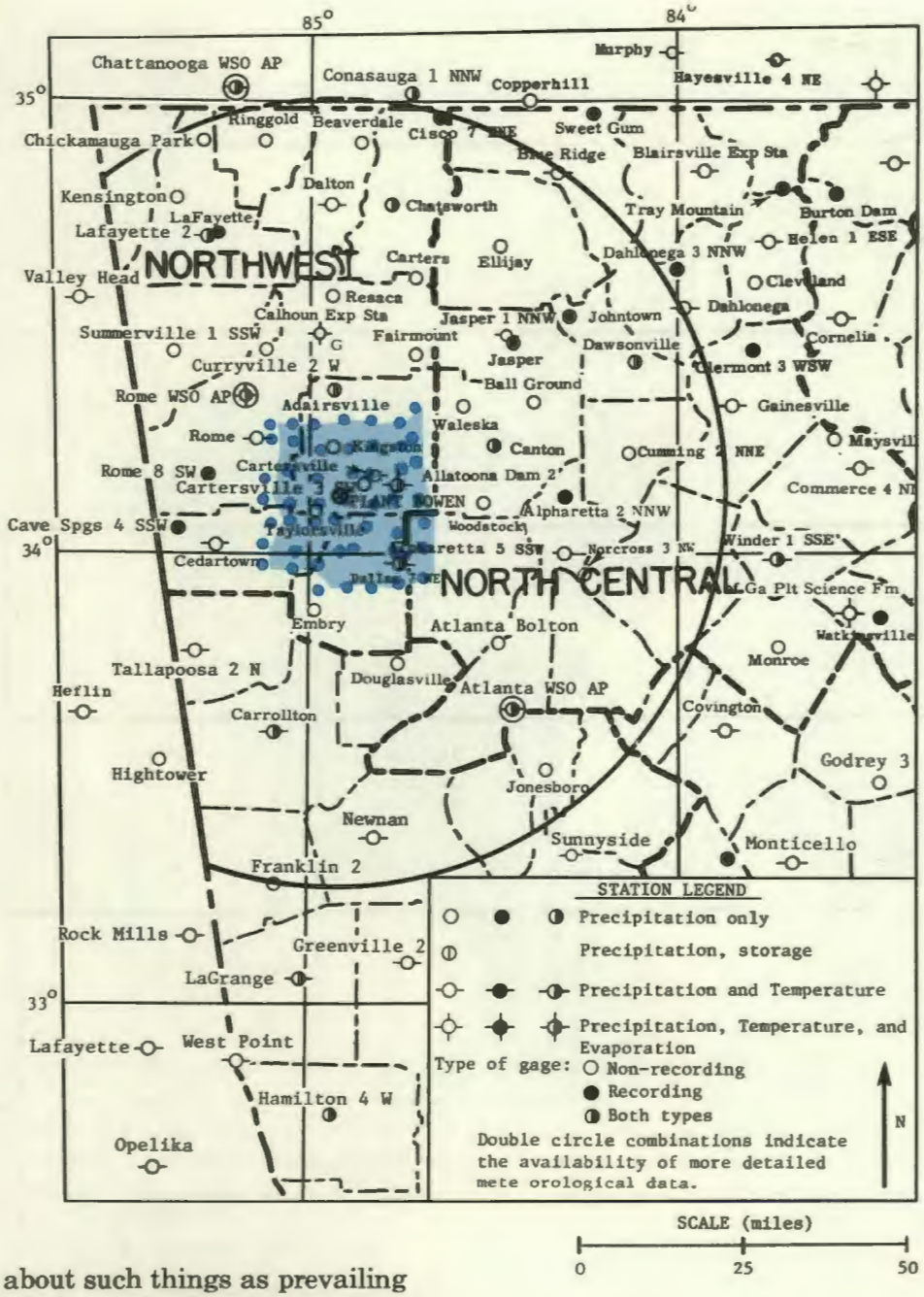
Climatological Study

We began by analyzing existing climatological data from Northwest Georgia. The National Weather Service (NWS) operates two major stations in the area, at

the Atlanta and Rome airports. There are an additional 57 weather stations within a radius of about 60 miles from Plant Bowen. Most of them record rainfall amounts on a daily basis. Data of sufficient quality and quantity for analysis have been recorded since 1949. In addition to rainfall records, wind data on both speed and direction from the two airports were used along with upper-air wind data taken at the Athens airport about 90 miles east of Bowen.

The purposes of the climatological study were twofold. First, we wanted to establish whether Bowen did, in fact, alter the rain patterns. Data taken before the plant started operation in October 1971 were compared with data of the postoperational period. These comparisons require careful implementation of the available statistical tools, and the results are not conclusive, since the post-operational period is too short for showing any definitive plant-induced effect above normal year-to-year changes in rainfall. Our second use for the long-term climatological analysis was to help lay the groundwork for the field study. It became apparent that a concise understanding of the climatology of the region was necessary before we embarked on a field study. We needed to know

Aristides Athanassios Nicholas Patrinos was born of Greek parents in Alexandria, Egypt. He attended a Greek high school in Cairo, where the second language was Arabic, the third English, and the fourth French. When his family returned to Athens, he enrolled in the National Technical University there, receiving a diploma in 1970 in mechanical and electrical engineering. That year he came to the United States, where he studied fluid mechanics with emphasis on wind-tunnel-turbulence instrumentation and geophysical fluid dynamics at Northwestern, earning his Ph.D. in 1975. The subject of his dissertation was a numerical study of the Chicago lake breeze. Before coming to the Engineering Technology Division at ORNL in 1976, he served on the faculty of the University of Rochester in New York. Here he is task leader for the Meteorological Effects of Thermal Energy Releases (METER) activities at ORNL, which concentrate on the potential precipitation-modification effects of large power plants. In this pursuit he performed the work in Georgia described here. Here he discusses the field trip with Phil Hayes (right) in front of his room-sized map of Northwest Georgia.



A grid of 49 weather stations was established around Georgia Power Company's Bowen Electric Power Plant, near Rome, last winter. The effect of large cooling towers on weather conditions in the vicinity is being studied.

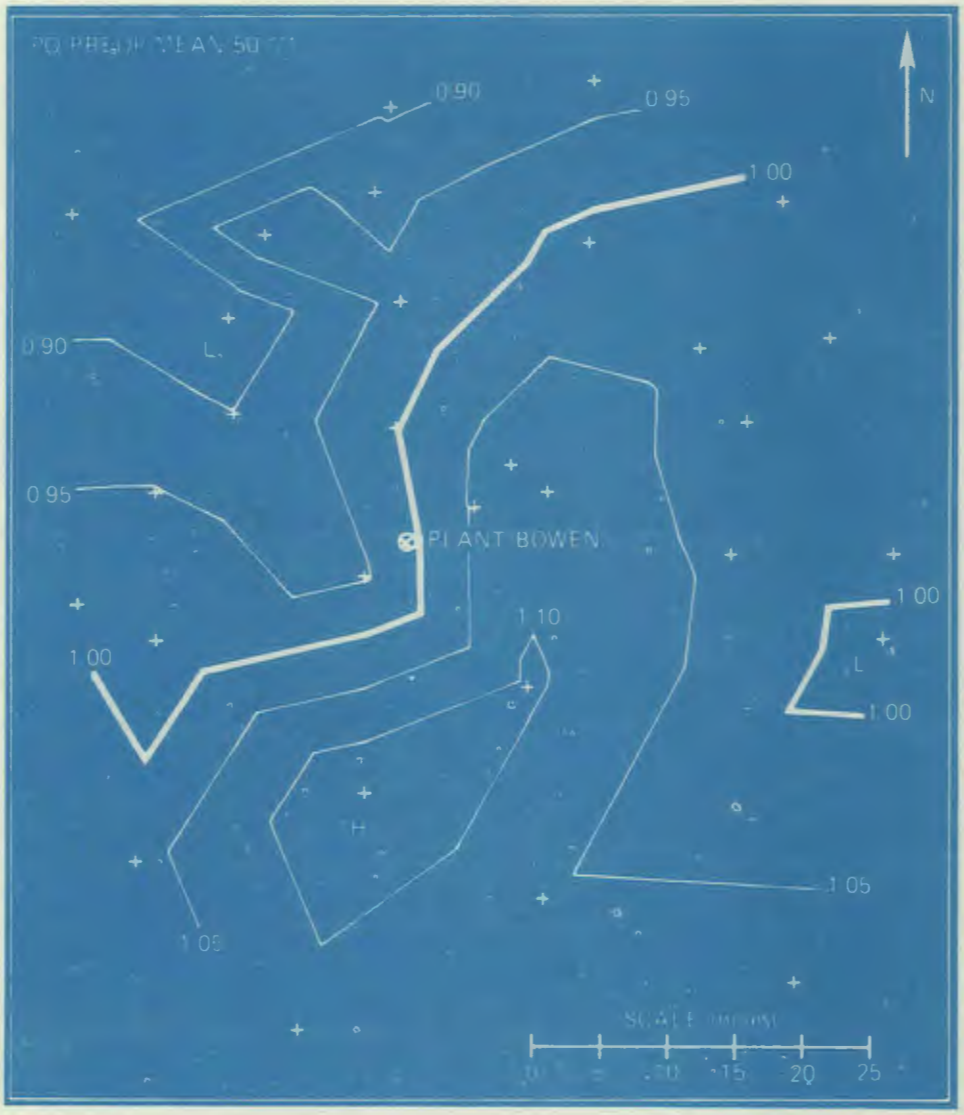
about such things as prevailing winds, predominant storm types and tracks, and effects of the local topography on rainfall patterns to help us in the planning and operation of the rainfall study network.

Oddly enough, the preliminary results of the climatological study suggested the power plant exercised a net positive influence on local rainfall. Study of winter (December through February) precipitation amounts showed strong increases in the area downwind from the plant. Winds during the winter season are predominantly from the northwest. These results are still tentative; nevertheless, they raise some very interesting questions that will, we hope, be answered by the field study. In that respect, time is working in our favor, since the extension of the postoperational period will improve the credibility of the results of the climatological study.

In working to understand the local climatology, we concentrated on natural rainfall variability. We computed spatial correlations based on monthly rainfall totals from NWS stations, and compared their patterns with topographical maps and wind graphs. The rainfall isopleths revealed a strong dependence on the direction of the prevailing storm tracks (SW to NE). We also found evidence that topography had an effect on the observed patterns, although not as strong as the storm-track dependence. There is a plausible explanation for these findings. Stations lying along the direction of the prevailing storm tracks are more likely to experience consistent relative rainfall amounts during storms than stations lying in a perpendicular direction. This can be highlighted in cases where rain is observed to fall in a narrow band along the storm track with no rain elsewhere. Another interesting finding of the correlation work is an approximately consistent linear relationship between spatial correlation coefficient and distance for all stations considered. It is premature to establish whether that relationship observes some "universal" law or is site specific.

Field Study

The obvious question one might pose at this point is, Why do you need a field study, if you have all that data? Good ques-



The lines show the ratios of normalized winter rainfall before the operational period to those after plant operation. A slight high is shown downwind from Plant Bowen.

tion! It is, in fact, fortunate that the density of the NWS network in Northwest Georgia is the highest in the whole state. Nevertheless, this density (about one rain gauge per 200 square miles) is inadequate for establishing definitively the precipitation effects of interest to this program. A state-of-the-art study requires a density of one rain gauge for about every 16 square miles to fully characterize precipitation patterns and to substantiate any claims of a plant-induced effect. Moreover, the quality of the NWS data is insufficient for a concise analysis of individual storms from which even a small effect can be measured. Thus, the concept of the METER-ORNL precipitation network was born. And thus it was that Phil and I happened to be in northwest Georgia knocking on doors.

The METER-ORNL network is now a reality. Forty-nine recording rain gauges are now in operation around Bowen in a square 7 by 7 grid, approximately 25 miles to a side. For tracking surface winds, we also installed four recording windsets at key locations, with an additional two to follow. We will also use data from the plant's own meteorological station a few miles away.

Long and careful preparations went into the installation of the network. The cooperation of the Georgia Power Company (GPC) was secured with a memorandum of understanding signed by both the GPC and Union Carbide Corporation, Nuclear Division. Bowen works as a base of operations, providing equipment storage facilities and occasional assistance (such as the use of stepladders and tools).

One important element of the study was a media campaign launched by ORNL's public relations office. Because we wanted to be able to install most of the rain gauges and windsets on private property, public acceptance of the project was imperative. The successful campaign covered local newspapers, radio, and TV, and contributed to the excellent response of the local landowners when we approached them for use of their land. We made these contacts and the instrument installations over a period of two weeks. On earlier exploratory field trips, we had established general areas for placing our instruments. During the first week, the six of us from the Heat Transfer-Fluid Dynamics Section visited preassigned areas in three groups, spoke to the landowners, and secured their permission to install the instruments at suitable sites (i.e., those with good exposure and away from obstructions and trees).

Despite extensive media coverage well in advance, this operation involved at least one humorous (in retrospect) incident. For two days the sheriffs of several counties were on the lookout for two suspicious-looking men, one tall and bald headed, the other full bearded and sinister, both traveling in a blue Toyota and allegedly impersonating GPC employees with "unspecified intentions." The would-be fugitives were, of course, Phil and me. The misunderstanding was eventually cleared up to everyone's satisfaction, although not before a phone call had been made to ORNL. The experience exemplifies the need for a careful public awareness campaign in preparation for any field study, especially in rural areas.

Installation was completed during the second week, and the network was fully operational on February 16, 1978. The installed rain gauges are of the weighing bucket type continuously recording the weight of rainwater in the bucket and calibrating it into inches of rain, on a weekly chart. A clock is attached, which operates with either a winding mechanism or with batteries. The windsets' recorders operate with a 12-V battery; the monthly chart, providing both wind speed and direction, advances at the rate of one inch per hour. Rich Saylor, as network field man, services all the gauges each week, returning to Oak Ridge to perform the data digitization. After computer processing, the data is ready for analysis of the various precipitation events. This includes computer contour plots of the rainfall amounts and establishment of the prevailing surface winds during those events. The NWS data are consulted for a better understanding of the general storm system, for rainfall amounts at other key stations, for detailed weather maps, and for upper-air data. Gradually, a storm profile emerges with information such as the type of activity (cold front, warm front, air mass, etc.), the prevailing winds (surface and upper-air), the duration, and the rainfall amounts over the network. Accumulation of that information forms the statistical base from which the plant's effects will be determined. Those effects will be explored in an upwind-downwind (or control-target area) framework, rather than through the preoperational-postoperational approach used with NWS data. The plant's daily thermal output is also monitored; it provides an additional parameter in the storm's data set.

Many of the rain gage stations occupied slopes on spacious country estates.

LINCOLN JUNG


LINCOLN JUNG

Setting up windset station No. 3 are (from left) Saylor, Hayes, Patrinos, Chen, and Miller. Plant Bowen's smokestack is in the background.

Long-term Study

The network will operate for five years. We think the accumulated data will provide satisfactory qualitative and quantitative evidence of an effect or a no-effect, whichever the case may be. Additional instruments, such as a weather radar unit or time-lapse photographic equipment, may be added should the early data indicate a need.

An additional dimension of the study, planned for FY 1979, will be introduced in an investigation of rainfall acidity. This work, which will be performed with the assistance of ORNL's Environmental Sciences Division, will examine the interaction of the smokestack plumes with the cooling tower plumes and the naturally occurring rain and its potential effect on the wetfall chemistry. The existence of the precipitation network and the established data-processing circuit will greatly facilitate this study and provide definitive answers to the growing concerns regarding wetfall chemistry.

Regarding the rainfall enhancement effect, current speculation indicates that, if there is any such effect, it will be small. The heat (about 5000 MWt) discharged by the cooling towers, divided equally between sensible and latent forms (the latter represents about 60,000 gallons of water per minute), is negligible compared with the heat released by even a moderate-size thunderstorm. Nevertheless, it is the persistent nature of the perturbation that might potentially release latent instabilities in the atmosphere and trigger convective storms. That is particularly possible with the convective situations that prevail during the summer months.

The results of these studies are expected to help the regulatory agencies in their licensing efforts as well as to aid the utilities in the planning and siting of future plants. ORNL is responsible to DOE's Division of Nuclear Research and Applications for the overall coordination of an effort that includes participants at Argonne National Laboratory; the NOAA Atmospheric Turbulence and Diffusion Laboratory in Oak Ridge; Battelle, Pacific Northwest Laboratories; Oak Ridge National Laboratory; Pennsylvania State University; and the Rand Corporation. No matter what the case might be, the METER-ORNL study will provide the answers and, as a fringe benefit, will enhance the current understanding of rainfall variations and effects of topography.

Rain plays an important role in everyone's life, and knowing more about it can only enhance the planning of those activities which are affected by it. One resident of northwest Georgia, when informed of the rainfall study, argued against it; he believed it represented an intervention in the Almighty's way. We believe he was wrong.

r&d achievement

A New Effect

A team of ten scientists working with ORNL's Van de Graaff accelerator in Building 5500 has discovered a "resonant coherent excitation" effect in a series of experiments in which beams of highly stripped positive ions of boron, carbon, nitrogen, oxygen, and fluorine are channeled at various energies through extremely thin crystals of silver and gold. The results, published in the March 27, 1978 issue of *Physical Review Letters,* show that as much as 50% of the ions penetrating 300 atomic layers of gold have their electrons excited when they pass by the rows of atoms in the crystal at just the right speed.

The ions which have been stripped of all but one electron (hydrogen-like) are aimed at pipelike channels between the ordered rows of atoms in a crystal lattice. Because each channeled ion avoids the atomic cores, it encounters only a few of the electrons in the crystal. If the single electron on the penetrating ion is tightly bound, there is a good chance that it will not be removed by collision with electrons in the crystal. However, as each ion penetrates, it passes between pairs of atoms lying alternately on horizontal and vertical planes that are spaced equally apart. If the ions pass through the electric fields of the atom pairs at the right velocity, they are perturbed at a characteristic frequency that excites them to the next (excited) atomic state. In an excited state, the ion's electron is more easily removed by collision with electrons in the crystal, and the effect is seen as an increase in the number of totally stripped ions emerging from the crystal at a critical velocity.

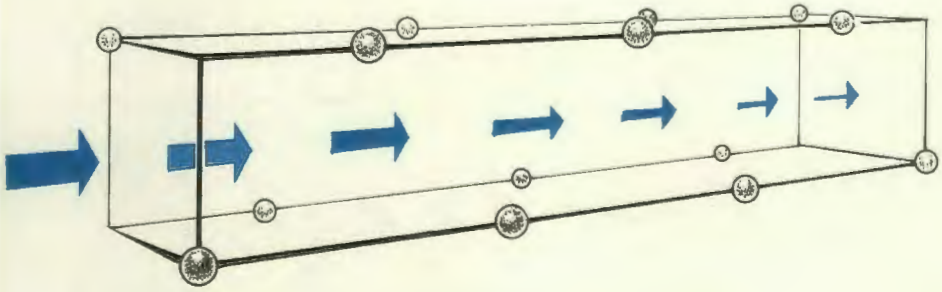
Charlie Moak, one of the experimenters, compares the effect to the range of sound frequencies heard when a child runs a stick clicketyclick along a picket fence. The faster he runs, the higher the frequency. The attainment of a critical velocity may be compared to raising the frequency of sound to the point of breaking a glass.

The effect is detected by passing the emerging ions through a magnetic field. Because the paths of the ions with higher charge are more strongly bent, the electronless ions are bent more than the ions retaining lone electrons. Two strategically placed detectors count the number of electronless and hydrogen-like ions as a function of velocity. By varying the velocity of the entering ions and counting the events, the scientists determined the critical velocity at which the maximum number of ions in a given beam would emerge electronless from a given crystal.

One of the more remarkable aspects of these experiments is the information gained on the state of fast ions penetrating solids and the degree to which states of such a potentially complex system can be described. For example, amplitude modulation (AM) is observed when the crystal is slightly tilted so that the ion passes from one channel to the next, every fifty or so atomic spaces. Another effect occurs because of the electron "wake" that the ion leaves behind as it moves through the solid. A swift positive ion passing through the "sea" of electrons in the metal crystal attracts electrons and creates a wake of increased electron density which trails behind the ion. Theoretical chemist Oakley Crawford has suggested that the electric field created by the negatively charged wake on the positive ion causes a splitting of the energy levels in the ion—that is, either of two velocities (frequencies) is able to raise the electron in the innermost shell of each hydrogen-like ion to the next level. This splitting then acts as a measure of the field on the ion.

One possible practical application of the resonant coherent excitation effect is that it could lead to an efficient method of producing atoms in highly excited states.

The experimental group includes Sheldon Datz, Moak, Herb Krause, J. Gomez del Campo, Pete Dittner, John Biggerstaff, and Phil Miller. Datz, Krause, Dittner, and Crawford are in the Chemistry Division, and Moak, Biggerstaff, del Campo, and Miller are in the Physics Division. Other members of the group are visiting Danish scientists P. Hvelplund and H. Knudsen, attached to the Physics Division.



If highly stripped ions are channeled through the crystal, they pass between pairs of atoms lying alternately on horizontal and vertical planes that are spaced equally apart. Should the ions pass through the electric fields of the atom pairs at just the right velocity, their lone electrons will be excited and, hence, are more easily removed by collision with electrons in the crystal.

Waste Heat Aquaculture at ORNL:

Can It Feed the Multitudes?

By SAM SUFFERN

A research associate in the Environmental Sciences Division, Sam Suffern holds degrees in biology, environment, and evolution. He earned his M.Phil. and doctorate at Yale, finishing in 1973. Before coming to the Laboratory in 1974, he administered part of Connecticut's Department of Environmental Protection. He is also a certified scuba diver and trained transcendental meditation teacher. His concern at ORNL is the effect, both destructive and productive, of large power plant cooling on aquatic systems. His towering pilot entrainment system can be seen at the east end of the aquatic laboratory, and inside he is cultivating *Tilapia* in large tanks and small. Here he describes his work with this excellent food fish from Africa.

WASTE HEAT—heat rejected to the environment by cooling systems—has been an object of study at ORNL for several years. Several uses for this resource have been explored, including dwellings, greenhouses, animal shelters, open-field agriculture, and desalination. Recently, ORNL has cooperated with TVA in the design and construction of prototype waste heat greenhouses. These designs have proved feasible, and much larger units are currently being installed at the Browns Ferry Nuclear Plant. About two years ago, members of the Environmental Sciences Division and the Engineering Technology Division began meeting informally to explore new ways of utilizing waste heat. It occurred to several of us that aquaculture held great potential and should be carefully examined.

Aquaculture in the United States to date has been largely oriented toward the intensive production of luxury protein. In systems of this type, fish (mostly catfish or rainbow trout in the United States) are stocked at high densities as a monoculture (only one species is grown) and are fed high-protein food pellets. Food amounts to 30 to 50% of the running cost of such a system. Due to the relatively high cost of production, the fish must be sold at high prices, limiting potential markets.

The basic precept of current aquaculture research at ORNL is that production systems should be designed to produce low-cost protein. Our basic thinking is that, although protein supplies are adequate in the United States at present, a large part of the world is already protein poor, and conditions of surplus are not likely to last much longer. The design of such a system is a radical departure from the capital-intensive monoculture techniques in vogue in the United States today. First, for reasons of system efficiency and stability, polyculture, that is, growing several species at once, should be used. Second, instead of using expensive high-protein feed, waste streams, such as sewage, animal wastes, or food processing wastes, could provide nutrient input.

Based on these ideas, a preliminary system concept was developed and subjected to extensive engineering and economic analyses. The current concep-

tual design is a sequential pond system, involving a succession of ponds dedicated to different cultures: algae, mixed species of fish, crustaceans, or rooted vegetation, into which controlled amounts of heated water and waste-stream nutrients are fed. Although details may change as a result of future research, the basic concept is expected to remain.

In order to convince an industrial heat producer (e.g., a utility) to participate in such a venture, enough basic R&D needs to have been done to ensure that the system is feasible. Because funding for aquaculture research has been virtually nonexistent at the federal level, I sought and obtained a Seed Money Program grant from ORNL and began the biological research necessary to demonstrate system feasibility.

Our first step was to develop species arrays of fish to be used. Three basic arrays were developed, based on the use of (a) exotic carp species, (b) tilapia species, and (c) indigenous species. The basic strategy used in setting up the arrays was to choose fish that were compatible and had complementary feeding niches.

Energy Trap

A brief explanation of system dynamics would be helpful at this point. An aquaculture system can be thought of as an energy trap. Energy is fed into the system in some form—in this instance, waste nutrients— and is captured by bacteria; by phytoplankton, small, free-floating aquatic plants; and by rooted aquatic vegetation. The energy is recaptured by the zooplankton which consume some of the algae and bacteria, and is recaptured again when the fish eat the algae, zooplankton, and aquatic vegetation. The nutrients, or energy, once trapped as fish flesh, can be harvested for human use. Heat fed into the system—in this case waste heat from condenser cooling systems—serves to accelerate the biological processes, increasing the rate of trapping. The real beauty of aquaculture systems is that they

take advantage of the efficiency of natural biological processes. For example, aquatic organisms expend little energy supporting themselves against gravity, and have a greater flesh-to-bone ratio than terrestrial organisms. Furthermore, because the culture organisms are cold-blooded, energy expenditure is minimal in maintaining warm body temperatures. Also, these organisms live in a three-dimensional world where nutrients are distributed throughout a volume, allowing much greater yield per unit of area than terrestrial systems.

After careful consideration of the possible species arrays, we decided to concentrate our initial efforts on tilapia. Tilapia, the fish of the miracle of the loaves and fishes, are cichlid fishes native to Africa, where they have gone through an extraordinary evolutionary divergence, producing species with markedly different feeding niches. Most are mouth brooders. Eggs are laid in a nest, then picked up by the female. The male next deposits sperm on the nest, and that, too, is picked up by the female. Fertilization takes place, with the eggs hatching in three to five days. The young are kept in the female's mouth until the yolk sac is absorbed, after which they begin leaving her mouth. For up to 15 days, they will return to her mouth when threatened. Young have been separated from the mother during brooding, and may be raised by themselves. Current thinking is that mouth-brooding is a mechanism for protection from predators.

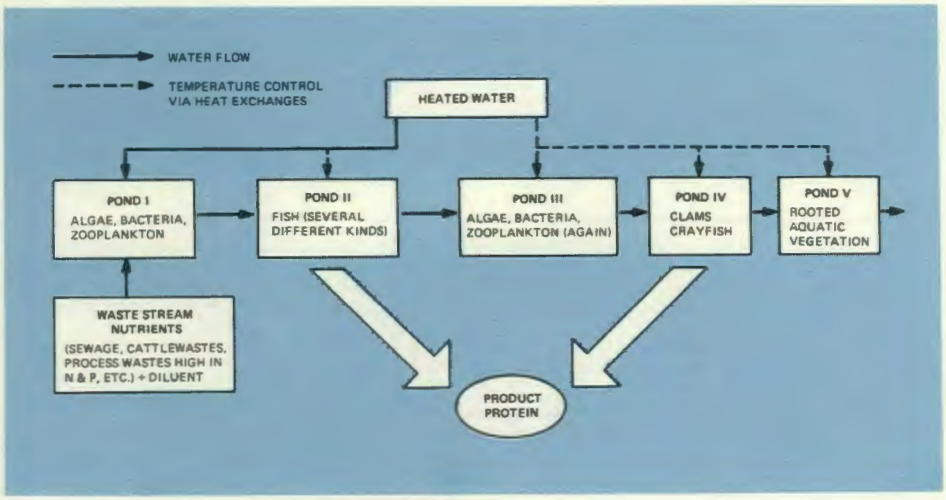
Why Tilapia Chosen

Several reasons underlie the choice of tilapia as the focus for our research. First, they are excellent food fish and are readily marketable. Second, they have been cultured extensively around the world and enjoy a reputation of having few disease problems. Third, as a result of worldwide culture activities, a good data base exists on many aspects of their biology. Fourth, literature reports on several species indicate growth-temperature optima from 25 to 35°C. This is substantially above that recorded for temperate-latitude fish, a factor that suits the genus well to waste heat systems where relatively high temperatures might be expected. Also, all tilapia species have about the same body shape and size, allowing some standardization of harvest and processing techniques. Production estimates for the tilapia association are much higher than those for the indigenous association. Although high production rates can be obtained with the carp, there are legal restrictions in much of the United States on their use.

Tilapia have one major drawback as a food culture organism; they become reproductively active at a small (<100 g) size. This could result in a crop of fish too small to market as human food, and is a problem which must be solved if the fish are to be practical for use in a commercial operation. At present, there are two ways around this dilemma. The first is sex reversal by hormone injection. This technique involves the administration of androgenic hormones to young fish, accomplishing sex reversal with about 95 to 99% effectiveness. The second method is hybridization. Several of the species, when crossed, produce monosex hybrids. Done carefully, this technique is 100% effective in some crosses.

We chose to use a monosex hybrid, the all-male cross of ♂ *Tilapia hormonum* by ♀ *Tilapia mossambica,* in our initial experi-

At press time, Suffern and Steve Gough were preparing a solicited three-year proposal to DOE to develop a waste heat aquaculture system designed for wastewater treatment and low-cost protein production. The goal of the proposed study is to determine optimal growth conditions of useful organisms that could be raised in the low-grade waste heat and nutrient-rich effluents discharged by various industries and municipal sewage plants. Once they determine the best conditions for raising selected plants and animals, the ecologists will match the species to the industrial systems that produce the desirable range of waste heat and nutrients. Such a scheme involving combined engineering and ecological know-how clearly has conservation value; it not only reduces energy losses to the environment but also yields valuable products. According to Bob Brocksen of the Environmental Sciences Division, the culmination of the three-year program may be a demonstration project in which ORNL ecologists monitor the growth of selected plants and animals in an environment of nutrient-rich effluents and reject heat from a proposed wood-fueled cogeneration plant that may be built by TVA on Kentucky Lake.



Conceptual design for a waste-heat aquaculture system.

mental program. This hybrid is known to be a plankton feeder, and appeared to be a promising candidate to fill that feeding niche in a polyculture array. Our initial experimental efforts were designed to answer questions which are fundamental to commercialization of the waste nutrient-waste heat concept. One goal was to develop the information necessary to design the thermal regime of a pond for maximum growth rate. A second goal was to develop estimates of the production potential of the fish in a system such as we have designed—necessary information for an accurate economic feasibility analysis.

Our research for the first year consisted of three related experimental programs:

1. delineation of growth-temperature relationships,
2. production estimate experiments, and
3. growth acceleration experiments.

Growth-Temperature Experiments

To define the relationship between growth rate and temperature, fish between 45 and 55 mm in length were divided into replicate groups and installed in 10 matched aquaria. The aquaria were maintained at eight different temperatures between 20 and 37°C, and the fish were fed Purina trout chow to excess. Laboratory fluorescent lighting was maintained at seasonal photoperiod (summer) by an outside photoelectric switch. The fish were weighed and measured biweekly; the experiment ran for 5½ weeks.

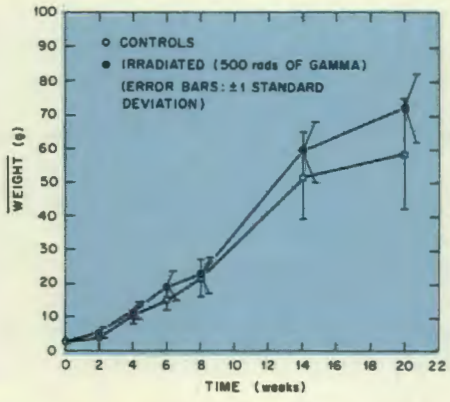
Growth at all temperatures was nearly linear throughout the experiment, with the largest increase in biomass occurring at 32°C. Substantial growth also took place at 26, 28, 30, and 34°C.

Production Estimate Experiments

To assess the viability of the waste-stream nutrient concept, the ORNL domestic sewage oxidation ponds were used as an experimental facility. The ponds are sequential. Sewage flows from a primary treatment facility into the east pond, where it is retained for about six days, then flows into the west pond where it is retained for another six days, before being discharged (receiving chlorination in the process) to White Oak Creek. The ponds are mixed with bubble aerators, and during the experimental period of July, August, and September 1977, they were isothermal (having the same temperature from top to bottom) in the 26 to 34°C range.

Small (5 gms) *Tilapia* hybrids were stocked in floating cages in both ponds at a density of 53 per cubic meter, and were weighed and measured biweekly. No feed was supplied; the fish grazed on naturally growing algae and zooplankton. As an interesting aside, the plankton association in the two ponds was strikingly different. The east pond had a dense culture of *Euglena* (a motile alga), whereas the west pond held a stable zooplankton culture, dominated by the crustacean *Daphnia pulex*.

Growth of the fish averaged over a gram increase in weight per fish per day. Extrapolation techniques were used to estimate production of a system maintained throughout the year at 26 to 34°C by the use of waste heat. Using extremely conservative assumptions (actual production figures were divided by a factor of 4 to allow for room in a full-scale system for harvesting boats and to compensate for decreases in growth rate in larger fish), estimated production was 51,620 kg/ha per year. As a frame of reference, this amount is more than 100 times the production of cattle per acre in East Tennessee,



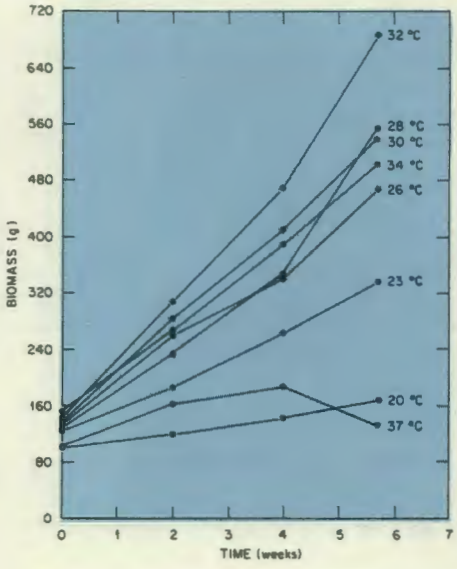
and more than 10 times the average production rate of catfish reared in ponds in the southeastern United States. At current market prices, this level of production should make a waste heat aquaculture system very attractive to industry.

Growth Acceleration Experiments

The objective of our growth acceleration experiments was to examine methods of increasing production rates. There is evidence that changes in growth rates in some animals can be caused by exposure to ionizing radiation. This effect was tested on *Tilapia* hybrids.

Young tilapia averaging 2.7 gm were exposed to 500 rads of gamma radiation in a cobalt-60 source (3.25 min). They were installed in a flow-through tank maintained at 30°C. Control fish were kept in a matched tank, and both groups were fed trout chow to excess.

Although this experiment was still going on when this issue went to press, the results already are noteworthy. Up to week 8, there was no difference in the growth patterns of the two groups. At that time, however, a continually increasing divergence in growth



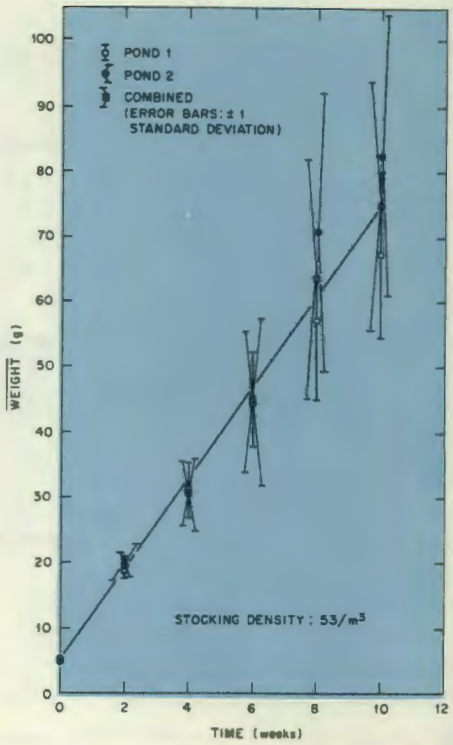
rate between the two groups began to be evident. At week 20, the irradiated fish averaged 20% heavier than the controls; the difference is significant at the 0.05 level.

At the conclusion of the experiment in June 1978, several fish from each group were to be sacrificed, preserved, and sent to G. E. Cosgrove (formerly at ORNL and now at the San Diego Zoo) for autopsy. Our present hypothesis is that the radiation has destroyed gonad tissue in exposed fish, and energy normally channeled there has gone into muscular development.

Conclusions

Waste heat–waste nutrient aquaculture incorporating *Tilapia* hybrids appears very promising. Our initial research efforts indicate economically favorable production rates and few biological problems with the concept, making it attractive to industrial users.

Future research in this area will be carried out by the Environmental Sciences Division this year. Using a series of small, lined ponds at ORNL, researchers will evaluate the production capacity of systems based on the use of chicken wastes instead of human sewage. Work will also be carried out on human sewage–based systems to examine bioaccumulation of toxic materials, bacteria, and viruses. Both of these efforts are directed toward resolving potential difficulties with Food and Drug Administration policies regarding the use of sewage as a nutrient for human-food crops. Efforts are also continuing to set up a full scale aquaculture facility as a demonstration project using the waste heat from the Oak Ridge Gaseous Diffusion Plant.



Rates of growth of irradiated Tilapia, *left, compared with normal fish; center, accumulated biomass growth rate is shown for different temperatures; right, growth of* Tilapia *hybrids in sewage pond cage culture.*

The ORNL sewage oxidation ponds.

As with many research efforts at ORNL, waste heat aquaculture research is the product of many people's cooperation. Marshall Adams, Marilyn Frank, and Chart Guthrie have all been instrumental in the experimental work. Gordon Blaylock, Bob Brocksen, Chuck Coutant, Dave Cox, Jeff Giddings, Jack Griffith, Steve Gough, and Jack Mattice contributed to conceptual development of the systems. Sam Beall and Mitch Olszewski have consistently kept the zealous biologists somewhere near engineering reality. We have received outstanding support from Jerry Hutchins and his staff at the steam plant.—JSS

lab anecdote

A Dash of Paprika

Andy Machek was a member of the SED, the Special Engineer Detachment of the U.S. Army Engineers. The SED was a group of engineers, scientists, and technicians who had been inducted into the Army during World War II, but who served in the Manhattan Project in a civilian capacity. Twelve hundred of them served in the Oak Ridge plants. Andy Machek, a scientific glassblower, worked at ORNL.

Eugene Wigner, on leave from Princeton University, had an important role in the Manhattan Project and came in September 1946 to ORNL to be its research director for a year. The phone book is democratic and shows no titles; when Machek found Wigner's name there, he thought it was the name of an old buddy and promptly phoned him. "Wigner, this is Machek." Wigner wanted to meet Machek, who wanted to back out of his mistake, but to no avail.

"Let's meet at the cafeteria for lunch."

"No," answered Machek, "I bring my lunch to work."

"Well, then, I'll bring my lunch to work tomorrow and join you," said Wigner. And join him for lunch he did.

Pop Miller was a Hungarian tailor who came to this country as a young man. His son founded Samuel's Men's Store in Oak Ridge and brought in his father as chief of the alterations department. Leo Szilard, like Wigner, was a Hungarian-born scientist who served in the Manhattan Project. His is the earliest patent for a nuclear chain reaction, conceived in England before he came to the States. On a visit to Oak Ridge, Szilard tore his trousers and took them to Samuel's shop for repair. He was discouraged that he would have to leave the trousers there for three days but decided to leave them anyway. When he gave his name, Pop Miller asked, "You are Hungarian?"

"Of course," was the reply.

"Well in that case we can do it right away."

—Herbert Pomerance

Activation Analysis at ORNL

A Very Personal Account

By ENZO RICCI

Enzo Ricci is now in the Analytical Chemistry Division. He came to the Laboratory in 1962 from a position in the Argentine AEC. He also was teaching at the University of Buenos Aires, where he had received his Ph.D. in chemistry. His interest in activation analysis, as evidenced in the accompanying article, has followed him throughout his career, and led last year to his receiving, with Dick Hahn, the American Nuclear Society's Radiation Industry Award.

BY SEPTEMBER 1962, when I arrived at Oak Ridge, my fate as an activation analyst had been established. As a fresh Ph.D. chemist at the Argentine AEC in 1953, I had watched the birth of the first Argentine man-made neutron from the reaction $^{7}Li(p,n)^{7}Be$ at a brand new 2-MV Cockroft Walton accelerator. Things have moved fast in Argentina since then. My team and I reported a new radioisotope, ^{61}Fe, to the first Atoms for Peace Conference in 1955, and I later traveled to Chalk River on an IAEA Fellowship, where I was introduced to neutron activation analysis (NAA) at the imposing NRX reactor. I was also shaken by the incredibly small size and great capabilities of my first multichannel analyzer—the "kicksorter"—which collected counts in 100 channels simultaneously. Imagine! I had made 20 irradiations (followed by chemistry) in 1954 to determine the energy of *one* gamma ray of 6-min ^{61}Fe in *the* Argentine single-channel analyzer.

The beauty of activation analysis is that it permits us to determine, with very high sensitivity, trace chemical elements in many matrices. The analysis is accomplished by bombarding the sample with neutrons, charged particles, or gamma rays, which then induce nuclear reactions and, thus, radioactivity in the sought elements; these elements can then be identified by their specific radioactive properties and can

J. F. Emery and L. C. Bate (l to r) working with the PDP-15 Nuclear Data Counting System at the High-Flux Activation Analysis Laboratory.

be determined quantitatively by counting. The basic equation for activation analysis, with W as the weight of the sought element in the sample, is very simple:

$$W = kA/(\sigma\phi SD) , \qquad (1)$$

where A is the induced radioactivity, σ is the nuclear-reaction cross section, ϕ is the bombarding-particle flux, S and D are factors related to the bombarding and decay times respectively, and k is a constant.

NAA at Oak Ridge

When I joined ORNL, a serious effort on reactor NAA was under way, based on the then active Graphite Reactor and the Oak Ridge Research Reactor (ORR). This work is still going strong today. But my assignments took me along other activation analysis routes, and these are the center of my story. For the same reason, because this is a personal account, some people and programs well deserving of credit will not be mentioned, simply because my contact with them was only superficial.

My arrival at ORNL coincided with Bill Lyon's appointment to head the Nuclear Analyses Group in the Analytical Chemistry Division. Over the years, Bill's mind has proven to have a rare and quite interesting makeup—it combines somehow the openness and creative free-flying freedom of an artist with the sober, unassuming, no-nonsense approach of a down-to-earth scientist, blended with the budget consciousness of a banker. He started a whole new era of activation analysis at ORNL by opening wide the door to R&D. While the effort on reactor NAA was continued with Juel Emery, Frank Dyer, and Lamont Bate, in 1962 two other members were added with me to Bill's group—Dick Hahn and Harley Ross. The idea was to engage in new, promising, and still unexplored areas of applied nuclear chemistry and activation analysis. And so we did!

My first experiences at ORNL occurred in fast NAA with Ed Strain. I first met Ed in Building 3017 on the hill, where a brand new 14-MeV neutron generator had been installed; he was eating his lunch. He pointed out to me for the first time the beautiful fall colors across the road to the north of ORNL. This relaxed mood was deceiving, however. Ed is a very hard worker, difficult to keep pace with. It did not take me long to appreciate Ed's efficiency and competence in his interaction with the neutron generator. He knew that instrument to the last screw—he could take it apart and put it together again with no hesitation. My work with 14-MeV neutrons was brief, but it set me on the path I traveled during all my involvement with activation analysis—development of new techniques, and identification and correction of errors in established ones. The latter resulted partially from my frustration at finding in the literature about a dozen different values for the cross

section of the commonplace reaction $^{27}Al(n,\alpha)^{24}Na$ with 14-MeV neutrons. Obviously, only one of them could be right...or maybe none was! Ed later published a table of cross sections and sensitivities which he had determined; he kept applying fast NAA to a number of ORNL problems, including alkaline metals. My contribution was to develop a method to account for the error caused by lower-energy neutrons in the generator output.

At that time, I began seeing activation analysis in a different light. Though my amazement at the elegance of the method did not dwindle, I saw that it required a "bag of tricks" to practice it proficiently—"tricks" or avenues that only the experienced analyst could know thoroughly. It was hopeless to try to learn activation analysis in one month, as some believed possible. The method was also sprinkled with pitfalls that could lead the uninitiated to make serious errors. I shared my first office with Frank Dyer in Building 4501, and I found that he was as concerned as I about those pitfalls. Frank was a most interesting and stimulating roommate. He had just published a comprehensive paper on NAA by delayed-neutron counting. We saw that some analysts ignored the error caused by second-order nuclear reactions at great cost to their results. So we published in the now defunct *Nucleonics* a set of graphs designed to allow calculation of second-order interference errors. While we worked on these computations, Frank and I engaged in all sorts of exciting discussions, from philosophy and politics to various areas of science—particularly physics and mathematics. Activation analysis is a physics method, and these discussions whetted my appetite for a broader knowledge of physics. So I set out to get an M.S. in physics at UT, which I finished in 1971. It was a wonderful experience, enriched by enlightened teachers such as Scotty Campbell, Wally Koehler, and, most of all, Lewis Nelson, all ORNL staff members at the time.

Bill Lyon had shared my concern about special avenues and treacherous pitfalls in activation analysis. He decided to set the record straight about them in a book which was to be coauthored by members of the Nuclear Analyses Group. Thus, we busily wrote the chapters and Bill edited the new *Guide to Activation Analysis*. Published in 1964, the *Guide* found its way to the bookshelves of many prestigious analytical laboratories, and it was reprinted in 1972. As a result of this writing venture, in late 1964 *Analytical Chemistry* invited Bill Lyon, Harley Ross, and me to write the "Nucleonics Review" for their biennial Fundamental Reviews issue. Our first contribution appeared in 1966, and updates have continued ever since; the "Review" is a critical evaluation of physics methods of analysis, emphasizing activation analysis and related efforts.

Charged-Particle Activation Analysis

Perhaps my most interesting time started in 1964 when Bill called Dick Hahn and me to his office to discuss the possibilities of engaging in an all-out effort to develop charged-particle activation analysis. We were very enthusiastic about the project, but the first question we asked ourselves was, Which particle do we use for activation? By then, Sam Markowitz, a professor at Berkeley, had shown that cross sections for ^{3}He-ion reactions tended to be large, thus promising high analytical sensitivities. Also, not much work had been done yet in nuclear physics with ^{3}He particles because ^{3}He gas was very expensive, and accelerators had to be provided with ^{3}He-recovering systems. This was a complication, but it also guaranteed a virgin field for new and original R&D. Another challenge was that the simple Eq. (1) could not be used to calculate results because the cross section σ varies with the penetration depth of the charged particle into the sample. So Dick and I embraced ^{3}He activation. By the time we were finished in 1969, we had published several papers on applied and pure nuclear science in *Analytical Chemistry, Analyst, Physical Review, and Nuclear Physics.* From an activation analysis viewpoint, the most important result of this work was that we succeeded in reducing the technically and mathematically complex process of charged-particle activation to the simplicity of a customary analytical method—NAA, for example—and made this process suitable for routine operation. We made Eq. (1) applicable and also proved the method's great sensitivity. In the years that followed, Dick and I were pleased to see many laboratories in the United States and abroad use ^{3}He activation analysis for surface trace determinations in a variety of materials, including semiconductors. It made us feel particularly good to hear

One way to tell whether someone has fired a handgun recently is to apply the NAA paraffin test. Engaged in a little forensic analysis are (left to right) F. F. Dyer, L. C. Bate, and J. F. Emery.

authors refer to the "Ricci-Hahn treatment" of their data.

This period brought very interesting experiences of a different kind. The experiments took place at the 5-MV accelerator and at the Tandem Van de Graaff accelerator, both in Building 5500, and also at the Oak Ridge Isochronous Cyclotron (ORIC). We tried to take greatest advantage of the 16-hr operation of the Van de Graaffs; during the first experiments, we organized shifts with the valuable help of Frank Dyer, Ed Strain, and Bill Ross (who is now with NRC in Washington). This was a very smooth collaborative experience, which proved that the Nuclear Analyses Group could interact as well in the laboratory as it had in writing the *Guide*. But most memorable was the close contact with Dick Hahn. He is a forceful, honest scientist and a warm, very active man at the same time. We agreed that he would be generally concerned with the pure aspects of our work, while I would deal mainly with the applied ones. It was a very rewarding arrangement that led to a harmonious combination of efforts. We observed that our work efficiency was *more* than just the sum of both our individual yields!

Indeed, this period was rich in personal experiences. Our work at various machines put us in contact with many interesting people in the Physics and Chemistry Divisions. I remember Paul Stelson, then a staff member—whom I had seen before playing the trombone at ORCMA concerts—running his own experiments at the accelerators. It is very nice that, as director of the Physics Division, Paul still finds time to do experiments... and to play the trombone with the Oak Ridge Symphony. A recollection also comes to mind of the time that Dick and I needed plastic foils to use as standards for light elements. Someone mentioned that there was a chemist in Building 4501 who could help us—his name was Lew Keller. Not only did Lew give us the foils, but he gave us, in his pleasant manner, useful hints about how to deal with the plastics. Dick and I were impressed by Lew's friendliness. Interesting, when one recalls that Dick went to work for Lew a few years later at the Transuranium Research Laboratory, later succeeding him as director of TRL.

There were funny moments, too. Our data were taken on paper tape, then converted into listings on a terminal in the basement of Building 5500. I remember one day when Dick and I sat on the floor of that basement cursing, in the midst of a tangle of black paper tape. The tangle was so fearsome that people stopped to see us struggle with it!

In the Right Place

A very important point became clear to me at this time—ORNL was an unusual and ideal place to try all possible avenues in activation analysis because it was a place where *all practical useful particles or radiations were available.* The charged-particle work had only been an example and a beginning. At that time, the Oak Ridge Electron Linear Accelerator (ORELA) was being built, and the High-Flux Isotope Reactor (HFIR) was beginning to produce ^{252}Cf, thus offering other interesting possibilities. My immediate attention turned to ^{252}Cf one day when Tom Handley came into my office with some intriguing suggestions (I soon found that creativity was natural in him). Here we had a radioisotope that fissions spontaneously; thus, for the first time we had a really portable neutron source for NAA. Now the question was, How good was it? What analytical sensitivity could we reach with a reasonable source? Our definition of "reasonable" was a source costing no more than $20,000 to $30,000. Tom and I set out to answer these ques-

tions. We obtained a ^{252}Cf source from the Chemical Technology Division and built a test facility in a cell that Lew Keller—again very congenially— provided for us at TRL. Aside from the ^{252}Cf source, a special feature of this system was a pair of 5-in. x 5-in. thallium-activated sodium iodide NaI(Tl) detectors which sandwiched the sample for counting. The results of our work confirmed our speculations. Although ^{252}Cf NAA was not as sensitive as reactor NAA, it was quite suitable for in situ or field applications. Furthermore, ^{252}Cf was *like* a small reactor for NAA—but a reactor which did not require any power or expert maintenance.

While Tom and I were involved with ^{252}Cf, we became intrigued by the ORELA. This high-energy electron accelerator was to be a source of neutrons having energies relevant to the U.S. reactor program. The neutrons would result from $(\gamma,x n)$ reactions induced by gamma photons from electron bremsstrahlung. Those photons promised to be copious and to have energies in the mega-electron-volt range—ideal for photon-activation analysis. There were complications, however. How could we place the specimens in this photon flux? At the ORR this problem had been solved by means of a pneumatic conveyor. But at the ORELA, the TA bremsstrahlung target produced a very narrow photon beam—quite unlike a reactor neutron environment—that would result in serious bombardment unevenness. What we now had to do was to design a sample holder, connected to a sample conveyor, which could rotate and precess simultaneously to guarantee even activation of the sample. Tom and I started playing with one of those toys with which one can suspend a pea in midair by blowing through a bent tube, and to our gratification we observed that the pea rotated *and* precessed! With the engineering help of Mel Willey we came up with an original design, based on the "pea levitator" (!) which met the requirements of our irradiation device for photon activation at the ORELA. [U.S. Patent No. 3,549,492 was granted to Enzo Ricci, T. H. Handley, and M. G. Willey for this bombardment device.—*Ed.*] The installation of the bombardment device in ORELA's target room was no simple endeavor; but again, with the friendly collaboration of all the ORELA staff—particularly Jack Harvey and Harry Todd—we finally got it in working order. With it, we proved that photon activation analysis is a good complement for NAA; elements which cannot be activated in the nuclear reactor show good sensitivities for photon activation, and vice versa.

Prompt-Reaction Analysis

There is a feature in most physics methods of analysis that is not present in activation, yet which has always appealed to me: the ability to count prompt radiations *during* bombardment, rather than to count radioactivity afterwards. This feature is attractive because it eliminates the need to follow radioactive decay for hours or days, thus drastically reducing the analysis time. In short, factors S and D in Eq. (1) vanish. Nuclear physicists have used prompt-reaction analysis for years to determine such parameters as nuclear-reaction cross sections, but not much use of this method in analytical chemistry had been reported by the late 1960s.

I found that Jack Gibbons and Dick Macklin were interested in using the 3-MW Van de Graaff in Building 5500 for this very purpose. I thought this a golden opportunity, and I joined them. Working with Jack and Dick was very pleasant. Dick has an attractive sense of humor, and I could sense already Jack's interest in the environment—which later put him on the national scene—from the beautiful Sierra Club posters he had hung in his office. During our collaboration, we successfully measured the profiles of lithium and fluorine diffused into graphite that had been exposed to molten salts. For this, we excited the low-energy proton reactions $^{7}Li(p,n)^{7}Be$ and $^{19}F(p,\alpha\gamma)^{16}O$ in the samples. The prompt counting was done again with the two face-to-face 5-in. × 5-in. NaI(Tl) detectors that had been so useful in the ^{252}Cf work. For my UT thesis, I later applied prompt-reaction analysis to the determination of $^{12}C/^{13}C$ and N/C ratios in biological samples.

Absolute NAA

When I started working in activation analysis in the early 1960s, the idea of using an absolute (first-principles) method by direct substitution in Eq. (1) was anathema to most analysts. There were good reasons for this: large errors could easily result because nuclear parameters for Eq. (1) (such as cross sections) were not yet well known for most elements. Activation analysis was largely based on the use of standards.

In 1964, the first edition of Guide to Activation Analysis *came off the press. Examining it are coauthors (from left) J. S. Eldridge, Ricci, J. E. Strain, H. H. Ross, W. S. Lyon, Jr., R. L. Hahn, and F. F. Dyer.*

Thus, if Eq. (1) is divided by an analogous equation for a *known* element (or standard, subindex *s*), the resulting ratio,

$$W/W_s = A/A_s \,, \qquad (2)$$

is much simpler, contains no uncomfortable parameters, and can be easily solved for W (since W_s is now known). However, while I was busy working on other avenues of activation analysis, great strides in the direction of the absolute method had been taken. The lithium-drifted germanium, Ge(Li), detector with its excellent gamma-ray energy resolution had practically displaced the old NaI(Tl) detector from NAA applications. This very resolution made computerized gamma-ray spectrum analysis quite simple at a time when dedicated small computers profusely invaded scientific laboratories and became part of all counting equipment. Finally, tabulated cross sections, branching ratios, gamma-ray energies, and half-lives of radioactive nuclides became certain and reliable.

All these years, Juel Emery had been active—in his always unassuming and quiet manner—in the basement of the ORR, performing NAA on many samples of interest to ORNL as well as to other laboratories. He took advantage of the above developments and included them in the program MONSTR, which he finished by 1972. This is indeed a "monster" program for a small computer (PDP-15). With little effort, the analyst can use it to help determine absolutely and sensitively several tens of elements in a sample by NAA. It does in about 30 min (irradiation and counting included) what before would have taken a week or more of hard work!

But important developments were happening also at the HFIR—Frank Dyer and Lamont Bate had designed and installed a new NAA facility, called the High-Flux NAA Laboratory. It features a PDP-15 computer for multielement NAA with Juel's MONSTR program. The HFIR analytical laboratory has the added advantage of a very high neutron flux, which results in proportionately high analytical sensitivities. After my long involvement with nonreactor activation analysis methods, the High-Flux NAA Laboratory appeared very attractive to me—NAA had come a long way from the single-element, comparator, hand-calculated method I had learned at Chalk River. Thus, I spent some time at this facility working mainly on tree-core sample analysis—a very intriguing technique that can uncover environmental conditions of past decades. Both the ORR and HFIR analytical laboratories have been involved in important ORNL projects. Among them in the last few years are the trace-element balance at the Allen Steam Plant and the uranium prospecting program NURE.

By 1974, I was still working at the HFIR facility, but with a feeling which grew stronger with time that I had tried all the practical activation devices at ORNL; I had described a full circle and come back to NAA. In short, it was time for me to leave activation analysis with good feelings about past achievements, mixed with nostalgia. And so I did in 1975, moving on to other challenging areas of analytical chemistry. It is nice to look back as I just did, to recall all the fun it was to be involved in such a variety of developments, and to have met such competent and interesting people along the way.

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awards and appointments

Ray Berggren has been selected to receive the E-10 Honorary Member Award for 1978 by Committee E-10 on Nuclear Applications and Measurement of Radiation Effects, American Society for Testing and Materials.

Cullie Sparks has been appointed to a three-year term on the Scientific Policy Board of the Stanford Synchrotron Radiation Laboratory at Stanford University.

Bill Wiffen has been appointed to the Editorial Advisory Board of the *Journal of Nuclear Materials.*

Several ORNL entries received awards at the 25th International Technical Communication Conference of the Society for Technical Communication in Dallas last spring. Winners were the ORNL *Review* (**Barbara Lyon**, editor), first prize in house organs; *Oak Ridge* by **Joe Gollehon**, second prize in brochures; *Fourteenth ERDA Air Cleaning Conference,* fourth prize in technical articles; and *Nuclear Safety* (**Bill Cottrell**, editor), fourth prize in technical journals. **Paul Blakely** has accepted the responsibilities of Program Chairman for the 27th ITCC held in Minneapolis in 1980. In the National Graphics competition of the ITCC, **Charles Tucker** received an Award of Distinction and an Award of Merit for his photographs, and **Bill Clark** received an Award of Achievement for his design of the brochure *Oak Ridge.*

Herman Postma has accepted the invitation of Governor James B. Hunt of North Carolina to be one of 13 members on the Board of Scientific Advisors to the newly established North Carolina Energy Institute.

David G. Thomas has been elected Fellow of the American Institute of Chemical Engineers.

R. J. M. Fry and **R. L. Ullrich** have been appointed to Scientific Committee No. 40, on the Biological Aspects of Radiation Protection Criteria, of the National Council on Radiation Protection and Measurements.

Hanspeter Witschi has been appointed associate editor of *Toxicology and Applied Pharmacology,* the official journal of the Society of Toxicology.

Liane B. Russell has been appointed to Committee I of the International Commission for Protection Against Mutagens and Carcinogens.

Paul Selby has been appointed to the Genetics Subcommittee of the National Academy of Sciences Committee on Biological Effects of Ionizing Radiation.

R. G. Haire was chosen by the Robert A. Welch Foundation to be a Welch Lecturer in its Lectureships in Chemistry Program held this past April.

Domenic Canonico received the Distinguished Service Award of the American Welding Society's Northeast Tennessee Section.

Tony Schaffhauser has been named chairman of the Research Committee of the International Precious Metals Institute.

Bob Hendricks and **Jim Weir** have been elected Fellows of the American Association for the Advancement of Science.