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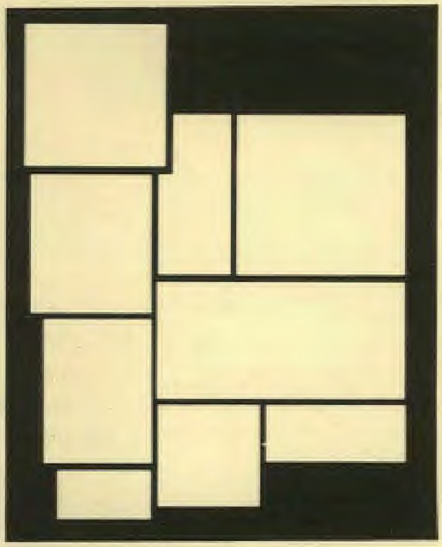
This issue:
ORNL and Industry



THE COVER: The montage depicts several scenes relevant to the Laboratory's interaction with the private sector. With the exception of the departments, every article in this issue discusses some aspect of technology transfer. Charging the Review *with such thoroughgoing coverage of one subject is a new use for the quarterly, and somewhat experimental. If it gets good response, it may be tried again. The editorial staff welcomes reactions.*

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Oak Ridge National Laboratory

review

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DEPARTMENTS

OAK RIDGE NATIONAL LABORATOF
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editorial

The Future For Technology Transfer

An Increasing but Balanced Role

The members of the staff of Oak Ridge National Laboratory play many roles in their efforts to fulfill the Laboratory's energy and environmental missions. Common to all, however, is a continuing desire by each person to see his or her work evolve into something that is ultimately beneficial to society. Initially that work might be a specific scientific result that enlarges a base of knowledge; it might be a technological accomplishment in the design of an important experiment; or it might be a bit of test data needed in a rush.

No matter what our ultimate hopes, or on what time scale we may expect their fruition, we need to determine the mechanisms by which we may expedite the transfer of our ideas and inventions to industry to be manifested in practical application. The routes of transfer are many: They range from publishing a paper in a scientific journal to actively seeking industrial interest in an ORNL invention. Whatever the route, there is a real commitment by the Laboratory to see that the transfer of technology does indeed take place.

There are numerous examples of success in meeting this commitment. The Laboratory publishes many papers each year; reports are distributed to interested people; the Office of Technology Utilization issues bulletins; we gain exposure and win awards for our inventions. The staff is widely honored and recognized for its contributions, a tribute that takes many forms—mention in trade magazines, receipt of national awards, overtures from industry, and joint development of programs with other agencies.

This issue of the *Review* points out the ways in which the Laboratory has been successful in the past, but it is apparent from the variety in these articles that there is no pat formula, no single route or method. It behooves each of us to be aware of the variety of ways in which transfer can take place; the failure of one method does not preclude the possibility of success by another route.

ERDA placed emphasis on the directive that the findings from the national laboratories move quickly to the marketplace. ERDA called such a move "commercialization" and encouraged its laboratories to expedite commercialization in all reasonable ways. So far, the Department of Energy concurs in this philosophy.

I foresee that ORNL will be increasingly involved: Technology transfers have already taken place at an exceedingly high rate over the past three years, with a sevenfold growth in the Laboratory's use of subcontracting. There are more industrial members on our advisory committees; we have many more industrial visitors to the Laboratory; there are more contacts and travels by Laboratory personnel to industrial areas; and there is more interest by trade societies, with more articles being written and more meetings being held. We are committed to more "program management" designed to speed up the transfer. These are all desirable and important trends toward increasing the Laboratory's effectiveness. There is, however, a danger in letting such a thesis become paramount in setting scientific and technical directions. An emphasis on too quick a payback can jeopardize the quality of technological developments and the basic research that lay the foundation for the future. It is our responsibility to conduct vital programs that build a sound technological base: programs of longer term, perhaps even higher risk, but ones whose strong fundamental research components will remain an essential, balanced part of the Laboratory.

In the future, ORNL will see more emphasis on commercialization and technology transfer, but it will do so in a setting that guarantees a vital research base—one that ensures that the continued development of underlying technologies accompanies technology transfer, and that they nurture and support one another increasingly.

—Herman Postma

Don Jared, until June of 1977 a developmental biologist, is the Laboratory's officer of Technology Transfer and Utilization in the Central Management Office. As he points out in the accompanying article, the Executive Committee suggested this year that a reaffirmation of the Laboratory's commitment to prompt transfer of its technology to industry take the form of an issue of the *Review* devoted in its entirety to the subject. ORNL has a long history of dedication to this pursuit. As early as 1962, an Office of Industrial Cooperation was established under Fred von der Lage. Although it ceased operations in 1969, its activities kept their momentum through the technology transfer officers in the research divisions. Then in 1971, the Nuclear Division mounted a four-plant effort which was coordinated by lawyer Mel Koons, at that time serving on the Nuclear Division's general staff as executive assistant to Roger Hibbs. Representing the Laboratory was Bob Lafferty, and after his retirement, Paul Blakely. In 1974, the ORNL Office of Technology Utilization and Commercialization opened, with Carol Oen as its head, still working through Koons. Today, the office is entirely within ORNL, and Jared works closely with each division to identify areas and stages of technology that are ripe for the open market. Truly, this calls for a more heightened awareness of the importance of technology transfer and utilization on the part of the scientific and technical staff of the Laboratory. Consequently, apart from the regular departments appearing in the magazine, the ensuing articles will be relevant to all aspects of technical interaction between ORNL and the private sector. In this article, Jared describes his office as it operates today.

Jack Young, Steve Kramer, Sam Hurst, Don Jared, and Ed Neister (l to r) gather around a laser provided by Neister's Phase-R Company.

Technology Transfer: the Commitment and the Barriers

By DON JARED

ORNL produces vast amounts of information which, for the most part, are available to anyone who asks. One might surmise that with all that information accessible to everyone, we would have little difficulty getting the public to use it, particularly because it is free and can at times be very profitable. Despite all the channels of distribution—journals, technical manuals, information centers, professional societies, information meetings, conferences—we are still failing to make effective contact with many potential users of our marketable new technologies. With the Laboratory's new mission to seek solutions to complex and immediate national problems, it makes sense that our technological developments be transferred to users quickly, and that the new concepts thus have rapid impact upon the economy and the environment. The rate at which solutions to problems will be tackled depends in part on how efficient we are in transferring our newly acquired knowledge to those who will make use of it.

In the United States, the time between the development of a new technology and its use and resulting effect on the economy averages 7.4 years. On the other hand, the transfer time for West Germany is only 5.2 years, and for Japan an even shorter period, 3.4 years. Japan can develop a new technology, manufacture a product, export it to the United States, and dominate the market

in half the time it takes the United States to put the same product on the market. Therefore, it should not be surprising to find that some of the first requests for information on ORNL's newly developed technologies often come from Japan and Germany.

Where the Barriers Lie

To facilitate successful transfer to industry of a given ORNL-developed technology, we must first find an industry that is capable of financing, manufacturing, and marketing the product; then we must ascertain that the right legal conditions exist. To some extent, the Laboratory can have an effect on the legal conditions of transfer, although these are primarily determined by the Department of Energy and by federal regulations. Our effect on the industry's part of the transfer is limited to identifying the industry and supplying information.

A report of a study performed for the National Science Foundation suggests that most barriers to technological innovation are institutional in nature. In transferring our technologies, the primary limiting factors are the policies and operating practices of the Laboratory, the federal government, and, finally, the recipient company. In each case, the organization must be committed to the transfer if it is to be accomplished.

Perhaps the greatest essential to transfer of technology, and one the Laboratory has responsibility for, is making industries aware of our new developments. We must

In the spring of 1976, the Office of Technology Transfer/Utilization, headed by Carol Oen, held a meeting on Industrial Thermal Insulation. Appearing on a panel at that meeting were, from left, R. W. Anderson, of the ERDA Division of Buildings and Industry; Carol Oen; Murray Rosenthal, associate director for advanced energy systems; and Ralph Donnelly of Metals and Ceramics Division.

be effective in furnishing information in a usable form to potential recipients. This information includes the concept of the technology and the special skills and techniques required in construction. Obviously we cannot furnish information on marketing and characteristics of the market that would be valuable to a prospective manufacturer.

A long-standing problem in transfer that we hope is now being solved is that of the patent regulations established by the governmental department and agencies which, in carrying out the intent of the Congress, determine the conditions under which a transfer may take place. In the past, anyone was allowed to license a government-patented technology; this discouraged industries from investing capital in a new technology, only to find after solving the production problems that a competitor had meanwhile entered the market.

Procedural barriers are also a great source of interaction problems. The negotiation, review, and approval processes frequently required take a year or more. In 1977, a new set of guidelines on patent policy was instituted by the Department of Energy. Although the impact of these guidelines is not yet clear, it is now possible for a company to obtain a greater than nonexclusive patent right on a DOE-patented technology under certain conditions. The way it now works, when a company requests greater rights, the Department of Energy will then advertise in the *Federal Register* that limited exclusive rights have been requested; if after six months no one else makes a response or request to license the patent, greater rights may be granted at a negotiated royalty.

We have an internal problem of keeping our attitude in step with our mission. Originally a place where keeping secrets about newly developed technology was most important, the Laboratory has become a place where it is now important to publicize new developments after all patent interests have been protected. This change in mission is not yet evidenced by a corresponding change in attitude. It is hard for some of the staff to understand that the commercialization potential of a newly conceived technology should be considered during the process of development. The sooner industrial considerations are taken into account in the development of technologies having marketable material, the fewer the modifications that will be necessary in the marketable product.

The Program

The Laboratory's industrial cooperation program came into existence in 1962. It was set up to identify Laboratory technologies that might have commercial potential and to offer them to industries for commercialization. ORNL's Office of Technology Transfer and Utilization serves as a liaison with industry and other groups, such as municipal governments and professional organizations, which have connections with industry. The office attempts to coordinate or set in motion programs that will increase the interaction between industry and members of the ORNL research staff who have technologies that might be commercialized. To this end, a technology utilization officer has been named in each division; conferrals with staff members can be

Carol Oen was head of the Office of Technology Transfer/Utilization from 1972 to 1977. Here she presides over one of the meetings held during her tenure.

arranged; consultants and services to industry are available; workshops, briefings, and seminars can be set up and coordinated; and bulletins on new technologies are published regularly.

Ordinarily, bulletins are usually considered among the less effective methods of technology transfer. However, a study of 106 technologies performed for the Nuclear Division in 1974 by J. R. McMillan and D. J. Wheeler of The University of Tennessee resulted in the following conclusion:

"In the rather short time the IC Bulletin *program has been in effect, there has been a high rate of technology transfer for the* IC Bulletin-*publicized technologies... seven different technologies have been completely implemented by nine of the firms contacted in this study; three other technologies are in the process of being implemented, and another six technologies are being considered for future implementation."*

Of the 106 technologies surveyed, 16 were implemented or were being considered for implementation by 21 respondents. This study shows that 27.6% of those people who receive additional technical information from us use it. Since the inception of the bulletin distribution program, 6500 recipients have requested supplemental information; 1600 of these were received in FY 1977. Eleven new technologies were described in the Technology Utilization/Commercialization (TU/C) bulletins in FY 1977. Seventeen have been distributed in 1978.

Present Interactions

The present interaction with industry involves many different programs, each of which functions somewhat independently; consequently, an accurate assessment is difficult. In an attempt to determine the extent of present interactions, we made a survey of Laboratory visitors in September 1977, which showed that we average approximately 1000 visitors per year for purposes of technology transfer. The number of telephone calls and letters involving industrial interactions would probably be twice that many. Survey data also indicate that approximately 10% of our visitors for technology transfer are from foreign countries.

Subcontracts

We spend $40 million per year on specialized equipment that requires extensive Laboratory-industry interaction. One highly visible example of this is the Holifield Heavy-Ion Research Facility; probably the largest development is the superconducting magnets being built for the Fusion Program. The Nuclear Division spends $11.8 million per year of the Laboratory budget on R&D subcontracts with industry, and we do approximately $1 million worth of cost-recovered work for industry annually.

A new legal arrangement for the Laboratory is the joint cost-sharing development contract. In this type of program, no funds are exchanged between the parties; each furnishes materials and/or personnel to accomplish the project. The Nuclear Division has entered into a number of such contracts, currently active or recently completed, for ORNL.

An example of Laboratory-industry-municipal cooperation is the ANFLOW sewage treatment project. This joint development contract project to build a pilot sewage-treatment plant was instituted by DOE among industry, the City of Oak Ridge, and UCC-ND in behalf of ORNL. Using the technology developed at the Laboratory and applied in this venture, Norton Company now makes the packing material for the process and sells it over the counter to industry and municipalities. The Tennessee Valley Authority is now considering an ANFLOW system ten times the size of Oak Ridge's for its Hartsville Nuclear Plant.

Current Projects

The energy data services and data book activities developed in the Energy Division at ORNL have grown in recent years. The *Transportation Energy Conser-*

vation Data Book and the *Buildings Energy Facts and Trends Book* are sponsored by DOE's Assistant Secretary for Conservation and Solar Applications. These statistical data books document past and current energy use as well as the factors that influence energy use in these two important energy-consuming sectors. The books are distributed widely and are used by federal and state energy planners. In addition, we have developed and now maintain extensive computerized demographic, socioeconomic, and energy data files which are used to respond to information requests from federal, state, and local policy makers.

The Solar Technology Transfer Program is sponsored by the Assistant Administrator for Conservation and Solar Applications. This program is designed to help stimulate the introduction of solar heating and cooling systems over the near future by disseminating information and providing technical assistance on potential solar applications to architects, engineers, vendors, and others involved in the building industry. Our program emphasizes working heavily with state and local groups to identify their informational needs and to provide workshops, training sessions, and other services to meet these needs.

The Annual Cycle Energy System (ACES) program involves preparation of design handbooks to promote ACES use in the residential and commercial sectors. There are currently at least a dozen buildings being constructed using the ACES concept. ORNL has participated, either in design or in technical assistance, in seven of these buildings.

The dynamic-membrane pollution-control process developed by ORNL's Chemistry Division has been used in the construction of pilot plants for the paper pulp industry and for the textile industry. With support from EPA and private industry, pilot plants have been built and are now being evaluated.

Some half dozen such programs are now being implemented in cooperation with industries and state and city governments.

Accelerated Interaction

In December of 1977, the ORNL Executive Committee formalized the policy to increase Laboratory interaction with industry. Among their recommendations were the following:

- to incorporate in the wording of the research proposals (the 189s) to DOE a commitment to commercialization;
- to increase subcontracting in order to get industry involved sooner in the development of a technology;
- to identify new programs (initially, at least two) in which ORNL may interact with industry through joint contract relationships;
- to establish relationships with companies having mutual interests with ORNL;
- to publish an ORNL *Review* issue devoted in its entirety to the subject of interaction with industry;
- to select at least one representative from industry for membership on every research division's advisory committee;
- to encourage exchanges of personnel with industry; and
- to enhance media awareness of developing technologies by increased use of industrial forums, trade journals, and similar communications methods.

This year, representatives of TRW were invited to ORNL for a briefing on our research programs. In May, TRW representatives returned to give a presentation on those capabilities of the company that relate to the work being done at the Laboratory. In April the Union Carbide Corporation Technology Committee, on which the Nuclear Division is represented by Herman Postma, visited the Laboratory for a briefing. There have been many follow-up exchanges of information since these visits, with both parties benefiting from the meetings.

In the transfer of technology, it must be noted that the user has a chance of losing much more than does the Laboratory. Recipient companies must choose from a large number of options the new products that they hope will be the most profitable; they stand to lose a great deal if they make the wrong choice. There is a built-in barrier between the technology supplier and the user; for example, cost effectiveness is a concern with the latter but is of little interest to the former. There is the added deterrent of government-generated red tape as well as the scant patent protection. If, as the NSF report on *Barrier to Innovation in Industry* states, the procedural barriers within the organization are the primary deciding factor, then how the Laboratory approaches its obligation to transfer new technologies is of primary importance. As can be seen from these recommendations, the management of ORNL is committed to eliminating barriers to industrial interaction.

take a number

By V. R. R. Uppuluri

Plus and Minus One

Birbal was a poet, musician, and a courtier of the great Indian emperor, Akbar (1556-1605). There are many legendary tales about the wit and wisdom of Birbal. Once three men came to the court of Akbar with the problem of sharing the wealth left by their father. The deceased father willed that the first son should get 1/2, the second son 1/3, and the third son 1/9 of the entire property.

The entire property consisted of 17 elephants. How could this be done? The solution proposed by Birbal was fascinating. He ordered the Royal elephant to be lined up with the 17 elephants. The sons took their shares of 9, 6, and 2 elephants and left the Royal elephant behind.

This may be considered as a "pleasant solution" to the problem (1/2, 1/3, 1/9; 17). It turns out that there are only seven such problems for which Birbal's idea works. They are (1/2, 1/3, 1/7; 41), (1/2, 1/3, 1/8; 23), (1/2, 1/3, 1/9; 17), (1/2, 1/3, 1/12; 11), (1/2, 1/4, 1/5; 19), (1/2, 1/4, 1/6; 11), (1/2, 1/4, 1/8; 7).

Bob Holmberg operates the 30-cigarette smoker used in the inhalation program.

Inhalation Chemistry

For a number of years, a sizeable fraction of Mike Guerin's bioanalytical section in the Analytical Chemistry Division has been engaged in R&D related to the hazards of cigarette tobacco smoke, as a direct outcome of the Surgeon General's Report of 1967 that warns of the dangers of smoking. Since then, the bioanalysts have performed research on the chemistry of cigarette smoke and have offered instrumental and engineering support to a number of biological teams throughout the country who are studying its effects. The goal of this effort is to develop a less hazardous cigarette. The work is supported both by the National Cancer Institute (NCI) and by the Council for Tobacco Research, an independent granting agency supported by several of the major tobacco companies.

In support of an NCI epidemiological study, the group is at present analyzing smoke from a worldwide assortment of commercial cigarettes. Some of the esoteric brands under investigation include Nyota from Kenya, Trust from the Philippines, Stop from Italy, and Double Happiness from Taiwan.

The proper delivery of cigarette smoke for inhalation testing to small animals, such as mice or rats, is a difficult task. The cigarettes must be puffed, and the smoke delivered to animals in a manner relevant to human smoking, yet with as much uniformity as possible so that the effects of subtle chemical differences between cigarette types are preserved. There are literally thousands of chemical compounds in cigarette smoke, each presenting a different and usually unknown hazard, with the concentration of each compound dependent on how the cigarette is smoked.

The ORNL group has been notably active in the design and evaluation of smoke-exposure apparatus. One system, the ORNL-Maddox Smoking Machine, developed originally for a collaborative NCI-sponsored study with the Biology Division, has now been manufactured and is extensively used by Battelle Northwest Laboratories. Another system, the SEM II, manufactured by Process and Instruments Company of New York, has had extensive ORNL input. This device gulps 30 cigarettes at a time and provides a continuous stream of smoke for biological studies. The SEM II, with its extensive accompanying instrumentation to monitor exposure levels, is being used by the Microbiological Laboratories Inhalation Facility in Bethesda, Maryland.

There has been an interesting spin-off from this work. The techniques developed for the analysis of the organic constituents of cigarette smoke are now being applied to the analysis of effluents from fossil-fuel-conversion plants, a subject of increasing interest to the Laboratory in both its energy and environmental involvements.

Asad Hyder of ORTEC and Rosa Young of ORNL's Solid State Division discuss the merits of laser annealing of silicon-based materials used for radiation detectors and solar cells.

Neutron Transmutation Doping and Laser Annealing of Solar Cell Materials

Two processes applied first at ORNL for fabricating photovoltaic (solar) cells are being used by industry. They are neutron transmutation doping and laser annealing of semiconducting materials. The first is used to introduce an extremely uniform distribution of phosphorus dopant in silicon, and the second is used to remove lattice damage as introduced by thermal diffusion or ion implantation of another dopant such as boron. The major goal is to establish an electrically active junction between the *n*-type (phosphorus) in the bulk of the silicon and the *p*-type (boron) near the front surface. Free electrons and positive holes are created when solar light is absorbed, and the junction then acts to separate these electron-hole pairs, thus building up a voltage difference that can produce a flow of electric current through an external circuit.

The first work on transmutation doping of semiconducting materials was performed almost 30 years ago at ORNL when Prof. K. Lark-Horovitz of Purdue University and his graduate student John Cleland used the X-10 Graphite Reactor for studying radiation damage effects. Recently, both German and American workers have shown that neutron-transmutation-doped (NTD) silicon gives significantly improved performance when used in the fabrication of avalanche detectors, high-power rectifiers and thyristors, and other electronic devices. Siemens Corporation, in Germany, was the first industry to adopt a large-scale use of NTD silicon for commercial fabrication of high-power semiconductor devices.

In 1975, John Cleland, Russ Westbrook, Dick Wood, and Rosa Young of the Solid State Division first applied NTD silicon for making solar cells. A desired and uniform concentration of phosphorus was obtained by irradiating large ingots in the Bulk Shielding Reactor for prescribed time periods. The silicon-30 atoms, which comprise 3% of normally available silicon, were transmuted to phosphorus-31 atoms; this method almost completely eliminates the nonuniform distribution of doping as obtained by conventional chemical means.

Two years ago, ORNL sponsored the first International Conference on NTD Silicon; this workshop spawned the planning of similar biennial conferences to be held elsewhere. The 1976 ORNL conference was attended by scientists and industrial

EG&G ORTEC, originally a spin-off industry from ORNL, is a user of the ORNL-developed laser annealing techniques.

managers from Japan, Italy, Germany, France, England, Denmark, and the United States. Among the American industries represented were Bell Telephone, Dow Corning, General Electric, General Motors, Hughes, International Rectifier, Monsanto, EG&G ORTEC, Western Electric, Westinghouse, Union Carbide, and Varian.

Due to a Department of Energy regulation, no DOE reactor can be used by any industrial group to produce NTD silicon for sale or device fabrication, unless it can be proved by that industrial group that no commercial or university reactor can be used. The largest producers of NTD silicon in the United States are Dow Corning and Monsanto, which use the research reactors at the University of Michigan and the University of Missouri respectively. Other large producers of NTD silicon are Wacker of Germany, Topsil of Denmark, and Komatsu of Japan (who sent representatives to the ORNL meeting). Other American industries that sent representatives are investigating or using NTD silicon in a wide variety of applications.

Laser annealing was tried successfully at ORNL last year as an alternative to thermal annealing for making solar cells. Rosa Young, Woody White, Greg Clark, and Jagdish Narayan of the Solid State Division found that pulses of coherent light from a Q-switched ruby laser (expertly operated by Phil King and Masanori Murakami of the Fusion Energy Division) effectively annealed radiation damage and completely removed crystal imperfections in the ion-implanted region. Furthermore, the localized heating effect of the laser light inflicted no harm on the electron-hole recombination properties of the phosphorus-doped base region, thus preserving the lifetime of its electrical carriers. In all these respects, laser annealing was found to be superior to thermal annealing. (ORNL is now investigating laser-induced diffusion for getting boron into silicon.)

There is rapidly growing industrial interest in the laser-annealing scheme. ORTEC is investigating the possibility of applying the technique to the manufacture of radiation detectors. Researchers from the Jet Propulsion Laboratory, Lockheed, and the International Rectifier Corporation have collaborated in testing the technique on materials considered candidates for low-cost solar cells. Bell Laboratories, IBM, General Electric, and Westinghouse Electric Corporation have all requested information from ORNL on laser annealing for application in making improved solid-state devices and power rectifiers (which convert alternating current to direct current).

A good example of interaction on laser annealing between an industry and the Laboratory is the case of ORNL and the Radio Corporation of America. RCA helped ORNL by coating silicon samples with antireflection materials and measuring the spectral response of the samples to each wavelength of light. ORNL cooperated by testing laser annealing on amorphous silicon samples sent by RCA. ORNL also used the technique on silicon and germanium samples supplied by EG&G ORTEC.

Ultrasonic Fish Tag

Power plants that are cooled by ambient waters give off enough heat to the surrounding lakes and streams to raise their temperatures significantly. The resulting effect on aquatic life, specifically on fish, is of interest to writers of environmental impact statements.

In 1973, two ORNL researchers developed a temperature-sensitive ultrasonic fish tag for tracking and monitoring the behavior of a variety of fish species in natural waters. This miniature ultrasound transmitter, devised by Jim Rochelle of the Instrumentation and Controls Division and Chuck Coutant of the Environmental Sciences Division, is now in use by private utilities and government agencies. The Duke Power Company, Northern States Power Company, Tennessee Valley Authority, National Marine Fisheries Service, Bureau of Sport Fisheries and Wildlife, and the Environmental Protection Agency have all put it to use. They began using the tag shortly after its original design was described in a published report by Rochelle and Coutant in 1973, and the following year at a workshop held by the University of Minnesota at the Cedar Creek Natural History Area.

At the aquatic laboratory, fish are harmlessly tagged before being returned to the lake near the Bull Run Steam Plant cooling pond.

The fish tag can be surgically implanted inside or outside the fish to measure internal body temperature or external water temperature. The tag is an electronic thermometer which transmits high-pitched sound waves at frequencies between 65 and 120 kc at distances up to 500 m. Fish implanted with these transmitters can roam freely during observation because the signal they transmit is received on shore or in a boat by a hydrophone system. One type of hydrophone is directional and locates the fish as it receives the temperature information.

Pulses (500 μsec in duration) are emitted by the tags of an ultrasonic carrier tuned to one of six frequencies. Temperature is coded by modulating the time between pulses which typically changes from 1.2 to 0.2 sec as temperature changes from 0 to 35°C. The tags on host fish can monitor internal or external temperature with an accuracy of ±0.2°C for periods ranging up to 12 months.

These tags have primarily been used in aquatic research studies of the water temperature preferences and selection patterns for different fish species. Most species are known to have general zones of preferred temperature, but they may make periodic forays in search of prey into water zones at temperatures well above the species' preferred level. Such behavior is readily monitored with the temperature-sensitive transmitters.

In another application the tags were used in muscle temperature studies which verified a physiological thermoregulation mechanism in tuna fish. Ecologists found that the tuna fish regulate their internal temperature in response to external temperature and that their swimming activity can be related to muscle temperature.

Electronic Instrumentation and Industry

In the first 30 years of ORNL's existence, many new electronic instruments were invented and later turned over to industry for quantity production.

In the late 1940s, P. R. Bell and Walt Jordan developed the A-1 linear amplifier (a retired example of which is displayed at the Smithsonian Institution in Washington, D.C.). This amplifier enhanced the weak signals from a radiation detector in a linear manner to permit spectral analysis by other equipment. The needs of the Laboratory exceeded the production capability of the Instrument Department, and a decision was made to involve private industry. Radiation Counter Laboratories of Skokie, Illinois, produced a limited quantity of these in 1948. At the same time, a scaler based on a Met Lab and Brookhaven design was manufactured from ORNL drawings by the now defunct Radioactive Products, Inc., of Detroit.

The workhorse of survey meters, the "Cutie Pie," was developed in 1943 and was fabricated time and again at ORNL. Its first commercial production by RPI took place in 1946. The Cutie Pie is still in use and has been updated many times. It served as a pattern for several dozen similar commercial types of survey meters that indicate the intensity of feeble current, induced by penetrating radiation in a tissue-equivalent ionization chamber. Radioactive Products also manufactured other instruments of ORNL design including Sam Hurst's count-rate neutron dosimeter (dubbed Rudolph because of the "red-nosed" detector).

George Holt of the Instrumentation and Controls Division recalls that "in the early days all of our designs were picked up by industry. The AEC encouraged us to feed industry with our design efforts. AEC's Technical Information Services (predecessor of AEC's DTIE and DOE's Technical Information Center) was the government vehicle used to help transfer information to industry.

"In 1948–1949, ORNL began outside procurement of instruments based on our designs but produced at lower cost by the private sector. Many devices were designed for our own needs, so we were not interested so much in seeking patents but having these devices built outside for our specific use to save us money and to allow us more time for research."

In the early 1950s, counting-rate meters based on the designs

The personal radiation monitor (PRM) chirps or screams in response to rising levels of gamma radiation.

of ORNL's Floyd Glass were produced by a host of companies including Radiation Counter Laboratories, Detectolab, Nuclear Research, Inc., Nucleonics Measurements, and Victoreen. These devices accepted pulses from radiation detectors and displayed the rate of arrival of the pulses in a meter indication, thus representing the intensity of radiation on the detector.

A successor to the A-1, the ORNL DD-2 linear amplifier was designed by Ray Dandl and

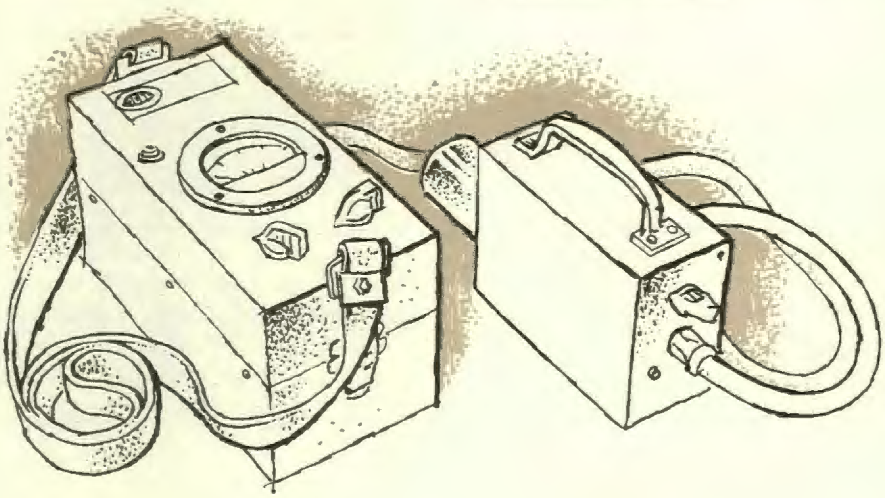
Edward Fairstein. It was produced by many companies including Franklin Electronics, Cosmic Radiation and Radiation Counter Laboratories, and Victoreen Instrument Company. In those days, a linear amplifier employing vacuum tubes weighed about 50 lb; nowadays, thanks to microelectronics, a linear amplifier chip weighs about one tenth of an ounce.

A flurry of activity in health physics instrumentation development occurred in the late 1950s and early 1960s in response to the accidental radiation excursion in Y-12 on June 16, 1958. A four-plant committee was created, and an effort was made to adequately monitor radiation at all of the facilities.

Because ORNL's needs were considerably different from those of Y-12 and the gaseous diffusion plants, specialized systems for ORNL's requirements were developed. Quantity production of devices such as the monitron, based on an early design of P. R. Bell, as well as transistorized portable and fixed health physics instruments designed by Floyd Glass and others in the I&C Division, was procured. Currently, nearly one thousand fixed health physics monitoring instruments are installed at ORNL, accompanied by about the same number of portable monitors, to ensure the safety of the personnel at the Laboratory.

Personal monitoring devices of many designs, such as the early pocket screamers and the R-Vox (a Floyd Glass development), spurred C. J. Borkowski and Bob Dilworth to develop the PRM, or personal radiation monitor, better known as the pocket chirper. This device chirps on receiving gamma radiation, starting at a rate of 16 chirps per milliroentgen per hour continuing on to a continuous scream at many hundreds of roentgens per hour. This fountain-pen-sized device, manufactured by the hundreds by Elgin Laboratories in Pennsylvania, was copied by many other companies according to their own perception of the specifications.

The fast-neutron survey meter was used to monitor neutron radiation levels at ORNL. Because it had a red nose, it was nicknamed "Rudolph."



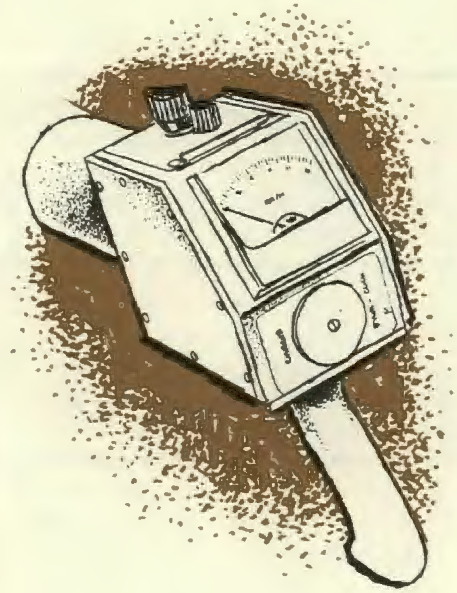
Manufacture of radiation detectors at ORNL has given way to purchase of these items from industry as manufacturers have added these items to their list of products. ORNL stopped making GM tubes in the early 1940s, and when scintillation detectors became available on the market in the early 1950s, this work also ceased.

Neutron counters designed by Roland Abele and others in the I&C Division were placed on contract with Victoreen. He also aided Reuter-Stokes of Cleveland, Ohio, in setting up production of these and other detectors for neutron, beta, and gamma monitoring. In the 1960s, Jim Blankenship and others (including John Walters) worked on and developed solid-state, surface-barrier-diode radiation detectors. Walters left ORNL to join ORTEC in their manufacture of these devices. Many companies are now involved in solid-state detectors; ORNL now relies entirely on industry to supply its needs.

The Laboratory participated in the work of the Atomic Energy Commission's NIM Committee, which was formed in 1964 to draw up specifications for standard modules to assure mechanical and electrical interchangeability of transistorized components. These modules are widely used throughout the world for research instruments, with some application in reactor-control and process-control instruments.

In the late 1960s, the I&C Division designed for the U.S. Office of Civil Defense a fallout-shelter monitor (containing an ionization chamber) and an aerial survey monitor. Manufacture of these was contracted out to Nuclear-Chicago Corporation, later bought out by Abbott Laboratories.

Technology transfer is as old as the Oak Ridge National Laboratory, as these developments demonstrate. Neither is it new as a policy of the federal government. About 20 years ago, Sam Sapirie, manager of Oak Ridge Operations, received a memorandum from George Quinn, director of AEC's Division of Production, identifying AEC activities that might be conducted by private industry.



Cited in the memo was this provision of a Bureau of the Budget bulletin: "It is the general policy of the Administration that the Federal Government will not start or carry on any commercial-industrial activity to provide a service or product for its use if such product or service can be procured from private enterprise through ordinary business channels." This policy still holds.

The Cutie Pie, first devised in the mid-1940s to measure radiation dose rate, is still in use.

Noise and Heat

Free electrons in any conductor are in continuous thermal agitation. This electronic motion causes minute voltages, which set up a measurable interference in the material's function as an electrical conductor. The hotter it gets, the greater the electronic agitation. First demonstrated in 1928 by physicist J. B. Johnson, this thermal noise is sometimes referred to as Johnson noise.

The Johnson Noise-Power Thermometer (JNPT), a new, basic thermometer invented and developed by ORNL retiree Cas Borkowski, erstwhile director of the Instrumentation and Controls Division, and T. V. Blalock of UT's Electrical Engineering Department, was first described in the *Review of Scientific Instruments* in 1974. It was developed and applied to measurements of temperatures in reactor irradiation experiments by Dick Fox, John Horton, and Bob Shepard. In April 1976, an industrial participation seminar attended by 22 representatives of industry was held at ORNL, and the design and operation of the JNPT were demonstrated. The laboratory system for JNPT measurements, packaged in NIM form (standardized modules), was redesigned for portability (the IPS-2) and modified to produce a direct-temperature readout. Complete manufacturing instructions, including parts lists, circuit diagrams, and etched circuit photomasters for both the NIM-modular and the IPS-2 measuring systems were provided to DOE's Technical Information Center, and have been published as industrial information packages CAPE-2567, -8, and -9. Several manufacturing firms have picked these up.

In 1977, the industrial prototype system IPS-2 was awarded the IR-100 award as one of the year's outstanding industrial products. Many requests for information on the JNPT were received and answered by ORNL's Office of Technology Utilization/Commercialization. The JNPT and its use in reactor thermometry were described at two sessions of UT-sponsored Tennessee Industrial Weeks in June and in November 1977. At these seminars, the use of the JNPT for in situ calibration of reactor plant resistance thermometers was proposed. A contract with the Electric Power Research Institute (EPRI) is now being negotiated for a plant demonstration and the qualification of a standard method for calibration. The principles and application of the JNPT were discussed in a technical talk to 30 members of the ASTM Committee E.20 on Thermometry in May 1976.

ORNL built and delivered a NIM-modular JNPT measuring system to Westinghouse-Hanford in May 1978 for use in the LOFT program. Technology for Energy Corporation in Knoxville is building a commercial version of the NIM-modular system, based on information from the CAPE packages.

Beads of Fuel

An important part of the commercial nuclear fuel cycle is the preparation of ceramic fuel materials for fabrication into a form suitable for loading into metal tubes. Gel-sphere-pac is a process for fabricating nuclear fuel which has important advantages over the conventional pellet process that was developed for contact operations. In gel-sphere-pac, the fuel material is fabricated in the form of dense, small spheres of the oxide (about 1 mm in diameter, and also smaller sizes) by an aqueous gel technique; these spheres are then poured into the fuel tubes. By using the proper mixture of sizes and appropriate vibration techniques, the desired fuel density is obtained. With gel-sphere-pac, materials handling involves only liquid solutions or free-flowing microspheres, vs the difficult preparation and processing of powders, including extensive internal recycle, in order to make pellets; this is particularly important in remote (shielded hot-cell) operations. Gel-sphere-pac fuel is also expected to give superior performance in reactors. In addition, the gel spheres appear to be an improved feed material for making the pellets themselves.

Gel-sphere-pac processes (formerly called Sol-Gel) were being developed at ORNL and elsewhere during the 1960s for the purpose of providing an acceptable method of remote fuel fabrication for both plutonium and thorium fuel cycles. The need for remote capability results from the penetrating gamma radiation associated with these fuel cycles. The continued recycle leads to the buildup of lead isotopes that give off strong gamma radiation, while the thorium cycle produces uranium-233, which also contains some U-232 that decays with a very penetrating gamma emission. The fast breeder uses the lead cycle, while the recent interest in alternative fuel cycles has generated renewed enthusiasm for thorium cycles, including the production of U-233 in thorium breeders. In addition, there is at present some interest in "spiking"; that is, deliberately adding (or leaving in) highly active fission products to discourage diversion of fuel for making nuclear weapons. Therefore, this work, which was halted by the AEC in 1971 due to a funding limitation, was resumed in 1977 under DOE sponsorship. In the interval, work was continued in Holland, England, Germany, Switzerland, and Italy. The ORNL work is being carried out mainly in the Chemical Technology and Metals and Ceramics divisions.

Another reason for the present interest in gel-sphere-pac is the potential for improved irradiation performance. The heat-up rate on commercial reactors is limited because of mechanical interactions between pellet fuel and the metal clad; this precludes use of nuclear reactors for load following and also results in an effective power derating of up to 4%. Sphere-pac fuel behaves more like ball bearings at the clad interface and, based on tests to date, will not suffer from heat-up rate limitations. For these reasons, there is currently potential commercial interest in gel-sphere-pac by EXXON, Westinghouse, General Electric, and Babcock and Wilcox. General Atomic and German industry have used gel-derived microspheres for many years in their high-temperature gas-cooled reactors, where the fuel is coated and imbedded in a graphite matrix. The British plan to use gel-sphere-pac in their fast reactors; the Dutch have done much work to demonstrate the process in light-water reactors; and the Swiss have prepared numerous irradiation test materials of (U, Pu) monocarbide for fast-reactor use by a modified gel process.

ORNL has recently demonstrated the preparation of good quality pellets from gel microspheres, using a simple press-and-sinter method. This approach is very attractive because it provides an improved feed material for making pellets, but still makes use of pellets, which are already licensed for commercial use. This route could thus provide a mechanism for the early commercial application of gel microspheres, while sphere-pac loading is in the licensing process.

W. L. Akridge, of the Oak Ridge TRW office, left, confers with colleague Donald Gray, TRW-Energy Systems Planning.

John Foster, vice president and general manager of Energy Systems in TRW, Inc., an international supplier of high-technology products and services, spoke to a number of programmatic decision makers at ORNL last May. At the time, program managers from many divisions of TRW visited the Laboratory and held a seminar for interested members of the staff on ways that the company, which serves the energy, industrial, and transportation markets, might interact with ORNL projects. Foster, who has been associate director of Lawrence Berkeley Laboratory, director of Lawrence Livermore Laboratory, and, more recently, director of defense research and engineering for the Department of Defense, brought to the subject of technology transfer and commercialization the broad perspective of one who has operated on both sides of the exchange. The following is an edited transcript of the talk he delivered at ORNL on May 17, 1978.

The Way It's Going to Work

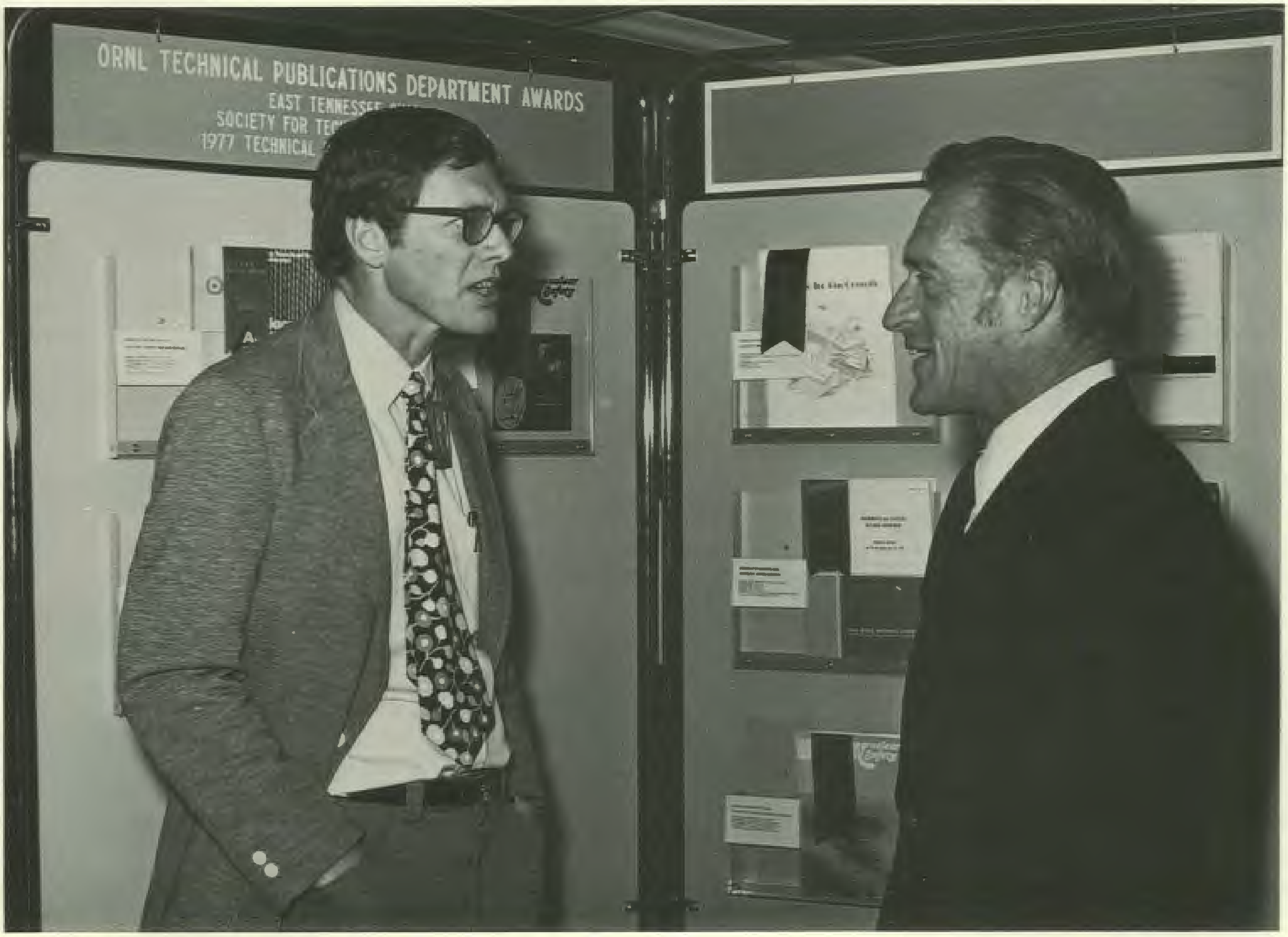
By JOHN S. FOSTER, JR.

Dr. Postma has suggested that I make a few informal remarks about national laboratories and about commercialization of energy programs. Let me start by asking this: Why do we have national laboratories? I ask this because why we need them and why they're important are sometimes at odds with what we are doing with them.

It seems to me that we have national laboratories because, as a technologically advanced nation, we face some very difficult problems and, as a democracy, we have a habit of ignoring very difficult problems until they get out of hand to the point of crisis. In addition, a national laboratory is expected to make important contributions to basic science and to identify and pursue initial applications.

Now, that means that the kinds of things that the laboratory should work on are problems that require very large efforts to provide solutions—that is, tough problems; otherwise they wouldn't be left to the labs: problems that involve large risks and generally take a long time in the sense of several terms of government administrations. A singular past example is the development of nuclear reactors. A current example is the fusion program. Those kinds of problems, when tackled in the commercial environment, even with government funding, undergo violent changes with changes in administration. On the other hand, it seems to me almost a miracle that the fusion program, born about 1950, has grown steadily and successfully over a period of some 27 years. We can only do this because we have a national laboratory structure.

Let me say a few words about where I think the strength lies in



John S. Foster, right, chats with Laboratory Director Herman Postma prior to his talk at ORNL last May.

this concept. I believe that this strength results from the knowledge of those who work in the laboratory that they are working on something everyone would recognize as being very important—moreover, important in a national way. That knowledge makes such a laboratory a very special place, with a rather unique strength as a scientific and technological center that is just head and shoulders above any other entity in the country, or in the world. A national laboratory has the people, the facilities, and the capabilities that go together to create a certain environment, and you can sense it when you walk in. It is a different kind of place.

What permits that environment? What permits it and maintains it is a contract—in ORNL's case, a contract between the government and Union Carbide. Such a contract is something that the Laboratory itself could not likely secure. You would just not be able to negotiate, on your own behalf, a contractual agreement that would permit the kind of environment you enjoy. I don't feel there is any great difference whether the University of California, the University of Chicago, or Union Carbide holds the contract. What seems important to me is that the contract should be held by a large, responsible, and independent entity that can cover for a national laboratory.

But with these strengths go some limitations and some potential weaknesses. One of them is that the jobs we're talking about are national jobs, and because they are national and tough and long range and very large, the Lab frequently cannot finish the job alone: you can't do it all. Yet there are very few among us who are willing to take on something that we can't see through; we

Jack Davidson ponders a point made by Peter Staudhammer, TRW-Applied Technology at last May's meeting.

often want to take it the rest of the way. The painful experience is, however, that the further we try to take the project, the more we risk the opportunity for ultimate success. It has been seen repeatedly that the more a laboratory holds a job to itself, the more it tends to be judged self-serving and lacking in sufficient competence.

Some years ago I wearied of hearing this line of argument, but I'm afraid it's true. A national laboratory has a limited charter and limited capabilities. When a national lab wants more of this or that for a program and it's denied, the possible reasons for the denial often bear close examination. The denial is sometimes expressed by the lack of a particular appropriation, but a close look at the fundamental question of what the lab is supposed to be doing and how well it is performing often discloses the root cause.

Another limitation lies in the fact that it is a *government* laboratory. It is not something that is just ours; it belongs to the people. We're the stewards; we may have nursed it through several decades, but it belongs to the people. It is funded from taxes paid by the citizens and by commercial and industrial organizations. This means that the government must have some positive control over salaries, the kinds of programs, and some of the procedures. This fact, in turn, controls the character of the programs and their pace.

There is another potential limitation: a national laboratory has a very limited constituency. If a laboratory gets into trouble, who goes to fight for it? How much clout do its advocates have? If the lab gets into an argument with other performers, it will soon be apparent that universities and industry have a larger constituency. This matter of constituency comes to the fore in the event that there is any heavy criticism on the part of performers who may be working or who may wish to work in areas that are in or adjacent to the areas that the laboratory judges to be its prime responsibility. In the initial phases of a program, there are the universities who wish to be involved; further downstream there are the industrial performers and perhaps in the end the consumers. It is important to guard against the possibility that these entities may become very concerned. It is important to limit the lab's role in such a way that it will be crystal clear to people on all sides—those in Washington, those in universities, those in the performing industry, and others—just why you selected the problem and why you've picked out a particular role. This has to be done very early in any program.

Once you identify a problem that's national, tough, and long term, finding the solution usually requires capabilities you don't have. So the first thing you think of is the need to hire another 50 or 200 people, and the need to make capital improvements. But you also ought to think about what you shut down. Each of us has failed to do enough of the latter. In fact, we do our best to keep everything going. However, it seems to me that in order to get and maintain that particular priceless mission, one must remove some of the smaller efforts—projects which, over time, just don't seem to be revolutionizing the situation nationally or changing the whole future of science. Exercising this selection process doesn't mean that there shouldn't be a lot of basic science going on in the lab. There must be, and for a very simple reason: many of the things that a lab can, in fact, provide come from its basic research; in addition, when one gets into trouble on a development program, one frequently must call on the small groups working on basic research. A laboratory's real strength must lie in its

scientific and technological excellence.

So, with this observation about why we have national labs and their strengths and limitations, I'll risk some comments on what we should try to do. One thing seems pretty clear: the lab has to decide what it wants to do. To fail in this task is to find out later from Washington what we have been directed to do. It may sound awfully simple, but finding out what's important—which national problems ORNL can and should tackle—really ought to take a fair fraction of the time of all of us. Of course, the reason we all tend not to work much on this task is that it's a heck of a lot easier to go back into the lab and work on some of the problems that are holding us up. But the fact is that if we don't like some of the missions or roles or procedures that are being assigned, it's frequently because we haven't spent enough time trying to decide what the real situation is and what we can do about it. If we'd make the effort to formulate that message and then just take it on up, we'd be way ahead of the poor folks who are so burdened down in Washington that they have no time to worry about these things. We must understand this point.

Just to give an example: We've had for many years a concern on the part of the administrations regarding proliferation. It seems to me that this is a problem which is of national importance. On the one hand, the people in this lab could well say, "Look, that's really just a political problem that is being blown out of proportion." On the other hand, a few key people in the laboratory might just make a dedicated effort and come up with an approach, a technological contribution which changes the whole situation. What I'm suggesting is that, all too often, we take the former course. We find it interesting to observe what's going on, since we know all about neutrons and fissionable material, and so on. But the thing each of us ought to recognize is that these problems are now our responsibility; *the founders of this laboratory and others like it know very well that it is the laboratory's responsibility to figure out what to do about such problems.*

A final point concerning national labs comes from a reflection on their management-performance history. As I see it, to the extent that the management of the laboratory is frequently on the front line of the Washington scene, there are mechanisms in our society that act to make things unnecessarily difficult for the laboratory. In retrospect, it's the low profile, albeit one of very high professional competence, that permits the laboratory to perform the job it wants to perform.

Let me now switch for a moment to the subject of energy and commercialization. First of all, it's not as if anybody's going to solve the energy problem. There is really no such thing as "The Energy Problem," just as there is no solution to "The Old Age Problem." What we have to do is to work on and solve hundreds of different but interrelated problems. Similarly, in the energy game, we don't solve the energy problem, we work on dozens of problems, none of them very easy. They'd be tough enough if they were just technical, or scientific, or engineering problems, but they have additional dimensions: economic, political, and international. The many aspects of energy permeate our society—and when we change the balance in the energy field, we may change the balance for millions of people. Clearly, such a situation calls for the use of "a systems-engineering approach," except that we are dealing with systems that are reluctant to be engineered. We do need to employ a systems approach and to recognize that there are too many simultaneous equations and even more unknowns.

In trying to figure out how to make the most of the time available to work the critical energy problems, it is difficult to persuade most people to go along with a particular approach. One approach that can be helpful is to look at the brief history of the way we have handled things in just the last four years since the Arab embargo. You see, we have, in

During a break in the TRW briefing at Environmental Sciences Division's new auditorium, Akridge (from left) talks with Roy Thoma.

E. E. Choat and P. E. Edwards, UCC-ND Engineering, take a break during the meeting with TRW program managers.

fact, run a rather complicated social-political-economic-technical-scientific experiment. How did we do? Are we satisfied with the way America has moved to cope with the complex situation following the embargo? I don't know anyone who thinks we have done very well.

The question is, in retrospect, aren't there some things that we have perhaps pushed a little too hard one way or another? Aren't there a few things that we could do now that would permit us to move a little more quickly? I take the view that things aren't likely to get better if just left alone. But the folks in Washington have taken steps to improve the situation. Things *are* beginning to move—nowhere nearly as fast as they ought, nor as fast as they could—but a few things are beginning to move in the right direction. The thing to do is to try to speed their progress. Sooner or later, every one of us is going to be judged by this history that we are creating. It really does bother me when my children talk about this subject, and I realize what a mess we could leave for these young people. All too soon, you know, they could be in terrible shape—and they will look back at what their folks did, spending a decade or two working on energy problems, apparently not very productively. If those kids are to have a chance, and their kids in turn, we've got to start moving more rapidly in the right direction.

I think among the things that are starting to go a little better are the following: people have stopped trying to find The Villain, the one who caused The Energy Problem. They have backed off a little from trying to hang the Seven Sisters—the major oil companies. The oil companies, in turn, I think, are undergoing a major change, not only in the image they present to the public, but in the way they are beginning to move. Many of the major oil companies now have come to the government, recognizing that the government *is* in the energy game, not just as a regulator, but now as a researcher, developer, demonstrator, commercialization facilitator, and so on. Just a few years ago, I recall none from the oil industry who would even consider turning to the government. In fact, the most commonly expressed solution was for the *government* to get out. It is a big change, in just a few years.

In the law that created ERDA, six conditions were set down that were to govern the expenditure of government funds in energy research and development. They related to the following kinds of conditions: the effort is urgent, industry cannot do it by itself; it is too long term and risky; industry cannot get sufficient capital; only the government has the facilities and capabilities; adjustment of regulated prices is too unwieldy, and so on. This list, I think, by and large, people in both industry and government can accept. However, I should point out that to my knowledge, most of the people in the DOE do not know of these conditions. The result is that we have a number of government programs now going on that probably do not meet these conditions. Admittedly, many of the programs were started before the formation of the DOE. Now that we have a Department of Energy with the same conditions on R&D expenditures plus regulatory authority, one of the important things to consider is a move toward changing the regulatory conditions which could induce private industry to move forward more rapidly with energy development programs.

But in any event, we can and should conduct energy research and development in selected government labs; the question is, how should we go about it? While I am not going to say anything new, it would be my hope that the government lab would have looked closely enough at each program it

has chosen to undertake to feel it really understands the situation. And because the laboratory has great professional depth, it will perhaps have found several technological contributions that could change the name of the game. Once the lab has come up with a research and development package with some feeling that the problem is important and that the chosen approach is a potential winner, I would suggest that the laboratory draw in, from the outside, professors in the universities who are studying the general field. Even though you *think* you really understand the problem, bring in the performing industry that would have to implement the solution later on, and the customers who would buy the product. I am suggesting a totally concurrent consideration of all aspects at the outset, with the hope that you may find out whether or not what you are planning to do really makes sense. You well know that the easiest thing in the world to do in a government laboratory is to proceed for the next several years, pursuing research and development. It is relatively easy to get the money; easy to go ahead and be happy doing the work. The problem is that, four or five years later, there is a great risk that you will look back and find out you have been wasting your time. Perhaps somebody else had a better idea. Perhaps it wasn't economic. Perhaps even if you could make it work, it couldn't be put into practice; and you would find that such things were true for a variety of reasons that were just not within your purview. You owe it to yourselves, you owe it to the laboratory, and you certainly owe it to the nation, to bring in these people early. Pay for them to come in and sit down with you for days or weeks, to try to identify all the risks, all the uncertainties. See what can be done to bring those uncertainties up front where you can address them at the outset.

A. H. Grobe and G. E. Schrader, TRW-Equipment Group (l to r) discuss the briefing.

In analyzing whether this or that energy activity represents a real opportunity for the lab, I would argue: do it in a participatory way. It made little sense, of course, to do this in the fusion program twenty years ago. That was clearly a long-range basic-research effort, and, at that time, not very urgent. But in the present situation, with the pressures on the laboratory to address critical national problems and to come up with early answers, I think you have to bring all of the considerations up to the front, at the outset, including many you would normally not think about.

Bob Farnham, left, converses with Eugene Christie, Frank Mertes, and Henry Bell, all of TRW-Energy Systems Planning.

I recommend, then, a participatory approach to understanding the concept and identification of a viable program to pursue, and then, a participatory approach in execution. And again, in order to minimize difficulties for the laboratory, I believe you should go out of your way to make it crystal clear what domain you choose to work in. It is important to make certain to others that there is also a place for them, a place where they are really needed, where the laboratory will not encroach.

And by the same token, the people in industry have to recognize the great contribution an institution like this can make to them in their efforts to carry out their jobs. After all, the business of sharing the responsibility for different aspects of a program, as you go forward, is at the heart of a successful commercialization effort.

information meeting highlights

BIOLOGY DIVISION, March 6-8

Metabolism of Carcinogens

A fraction of the chemical compounds being introduced into the environment by modern civilization may be potential carcinogens. Such compounds induce their tumorigenic effect in specific organs; for example, nitrosamines cause tumors in livers. The mechanism by which this takes place has been an object of inquiry. One assumption is that as the compound is metabolized, it becomes mutagenic to the body's cells, which may be the initial event that triggers the conversion of a normal cell into a malignant one. In order to test this theory, three events must be demonstrated. First, the carcinogens, when exposed to cells from a susceptible animal, must be shown to be metabolized to mutagens. Second, the same metabolites that induce mutation should also induce malignant cell transformation; and third, the material's conversion to a mutagenic metabolite should be shown to be related to its organ specificity.

Eli Huberman and his colleagues have found a simple method to show the metabolic conversion of chemical carcinogens into mutagens for mammalian cells, and that the degree of mutagenicity is related to the degree of potency of their carcinogenicity. They have performed this in a rodent-cell-mediated assay with a large number of compounds including the common environmental contaminant benzo(a)pyrene. In their work they have identified the major mutagenic metabolites of benzo(a)pyrene and have established its role in malignant transformation. In addition, using these and other chemicals, they have established in vitro a relationship between mutagenicity and organ specificity. Thus they have satisfied three criteria that are in agreement with the somatic mutation theory. The critical factor in conversion of a procarcinogen into a mutagen depends on the balance between the production of the mutagenic metabolite and its destruction by the cells. Huberman has also succeeded in defining the target size for in vitro malignant cell transformation. He is quick to say that this process deals with the first step toward establishing a cause of cancer; once mutation has been established, many other factors serve to determine the cells' development into a malignant tumor.—*BL*

ANALYTICAL CHEMISTRY, March 28-30

A New Technique for Safeguarding Nuclear Materials

Keeping close tabs on nuclear materials present in nuclear power plants and in fuel-reprocessing and fuel-refabrication facilities is considered essential to provide adequate safeguards against the clandestine diversion of uranium or plutonium for making weapons either by governments or by terrorist groups. One way to be reasonably certain that plutonium has not been stolen from any light-water reactor is to sample its spent fuel in dissolver solution and analyze its uranium/plutonium content, which should have a ratio of about 100 to 1 if no tampering has occurred. Inspectors from the International Atomic Energy Agency have been obtaining samples of 10 to 30 μg apiece because this quantity is required for accurate analysis with conventional mass spectrometers. Such sample sizes necessitate the use of shielding for safe transport from the reprocessing site to the analytical lab due to attendant radioactivity.

ORNL analytical chemists have now developed an ion-exchange "resin bead" technique and a tandem magnet-type mass spectrometer (equipped with pulse counting for ion detection) which permit the collection and analysis of nuclear-fuel samples in amounts 3 to 4 orders of magnitude smaller (nanogram or picogram levels) than conventional techniques require. Because the resin beads are as small as sugar grains and pick up trace quantities of uranium and plutonium, they pose virtually no radiation hazard and can be easily transported on microscope slides without expensive shielding. Besides reducing the need for shielding, both for transportation and laboratory analysis, the bead technique also offers simplification in the chemical preparations that remove fission products and eliminate interference from actinide isobars (isotopes of the same nominal atomic mass such as americium-241 and plutonium-241).

The technique—developed by Joel Carter, Ray Walker, and others—involves using a basic anion resin to selectively adsorb plutonium and uranium from nitric acid solutions containing dissolved spent reactor fuels. A single bead can be used for establishing the isotopic composition of both plutonium and uranium. Because plutonium is much more strongly adsorbed on the bead than uranium, there are approximately equal amounts of each element present. Fission products are removed because they do not adsorb.

In addition, if quantitative measurements are desired, the nitric acid solutions may be spiked with enriched isotopes of uranium and plutonium, and isotope-dilution techniques can be utilized. Precisions obtainable by this technique are comparable to those obtained from solution loadings of 10-100 times as much material.

To exploit fully the technique of resin-bead-sample loading, it is essential to have the capability of analyzing sub-nanogram quantities of plutonium and uranium. Mass spectrometers developed at ORNL by W. H. Christie, D. H. Smith, H. S. McKown, and others have such capability due to their pulse-counting detection systems, in which each ion is counted individually as it arrives at the collector. In addition, because there are two tandem magnetic stages, these instruments have the ability to measure minor isotopes to high precision. Precise knowledge of these minor isotopes offers additional fingerprinting safeguards information.

Such instruments are not available commercially. (There are fewer than ten in existence, three of which are at ORNL.) However, the combination of features these instruments possess is ideally suited to safeguard requirements, which prompted the IAEA to contract with ORNL to build one for them. The instrument was installed at the IAEA's Seibersdorf Laboratory in the summer of 1976 and has been operational since then.

There are further technology transfer aspects to these developments. ORNL personnel take turns guiding the operation of the ORNL-built spectrometer located outside Vienna, Austria, where IAEA is headquarterea. ı his year H. S. McKown is in Vienna representing ORNL. In addition, ORNL personnel are planning to demonstrate the resin-bead-sample preparation technique for IAEA inspectors at the WAK Reprocessing Plant in Karlsruhe, West Germany, and at the reprocessing facility owned by the Power Reactor and Nuclear Fuel Development (PNC) Corporation in Japan.

Work on the resin bead technique and the mass spectrometer development has been supported by DOE's Division of Physical Research, but their promise for nonproliferation purposes has sparked the interest of the Division of Safeguards and Security into providing funds for further applied development. This achievement is one more example of spinoff from basic research into practical areas.—*CK*

ENVIRONMENTAL SCIENCES, April 11-13

Air Pollution and Plants

Large acreages of forest and agricultural crops in the United States are currently exposed to polluted air at levels that may cause damage or inhibit plant growth. These air pollution stresses on vegetation—largely caused by primary and secondary products of fossil-fuel combustion—occur as a result of sulfur and nitrogen oxides, ozone, and rain that is 10 to 40 times more acid than normal over much of the eastern United States.

ORNL ecologists Sandy McLaughlin and Dave Shriner are attempting to measure the impacts on plants of present and projected future stresses from sulfur dioxide, ozone, and acid rain. By using a controlled-fumigation chamber and an acid-rain simulator (both designed at ORNL), they have tried to reproduce the levels and chemical compositions of pollutants to which plants are typically exposed. Their laboratory and greenhouse studies are aimed at determining the concentration limit for damage to vegetation by single and combined pollutants and at identifying suitable plant responses to measured low-level stresses.

Their laboratory studies with sulfur dioxide have indicated that significant, but apparently temporary, reduction in photosynthesis may occur at concentrations less than the current Environmental Protection Agency air-quality standard for sulfur dioxide. When sulfur dioxide exposures were stopped, kidney bean seedlings in the fumigation chamber recovered within 24 hr their ability to synthesize carbohydrates in the presence of sunlight.

In the acid-rain studies done in a greenhouse, growth of kidney bean seedlings was reduced as much as 10% when the seedlings were subjected to rain having acidity levels typical of the Oak Ridge area. The results suggest that local vegetation could be damaged if area rains become more acidic due to increased air pollution.

Field studies were started this summer to measure present pollution impacts on soybeans and tree seedlings. These studies use field chambers supplied with air that has been purified by charcoal filtration to test effects of local levels of pollutants and to allow comparisons of plant growth in polluted air and in air cleaner than normal.

The group is also collaborating with fellow ecologists Hank Shugart and Darrel West in the use of simulation models to study long-term impacts on forest systems. Results to date indicate that growth reductions as low as 5 to 10% may significantly alter the structure and dynamics of eastern forests. Resistant species (white oak) and some fast-growing species (yellow poplar) may undergo positive growth responses with added air pollution stresses, whereas other species (black oak, black cherry) may exhibit much greater than expected growth reduction due to changes in their competitive potential.

Plutonium in the Environment

Plutonium is being produced by light-water reactors and could be made in large quantities if fast breeders are built. Although recycle technologies will be designed to recover as much plutonium as possible from spent fuel in LWRs and breeders for reuse as reactor fuel, there is a chance that a small amount of plutonium will be released to the surrounding water and land. Other long-lived actinide elements that may enter the environment from nuclear fuel cycles are uranium, thorium, curium, americium, and neptunium. Studies are under way at ORNL to evaluate the behavior of these actinide elements in the water, soil, and plant and animal life in a 30-year-old contaminated floodplain forest.

Based on field studies of the plutonium-contaminated floodplain and on mathematical models, ecologists Roger Dahlman, Ernest Bondietti, and Chuck Garten concluded that less than 0.25% of plutonium in the floodplain ecosystem resides in the vegetation and trees in the forest. Soil was found to be the major repository for plutonium. The extremely low solubility of plutonium in water is believed to account in part for its low concentration in plants. Studies by Garten and Bondietti in collaboration with Ray Walker of the Analytical Chemistry Division indicate extremely low concentrations of plutonium, uranium, and thorium in the bodies of animals, such as opossums, woodchucks, raccoons, rabbits, shrews, and field mice. Because uranium is more soluble than thorium and plutonium, the ecologists detected greater uptake of uranium by plants and animals than of the other two actinides. People also show higher relative accumulation of uranium over thorium as a natural result of natural exposure to uranium and thorium, which are ubiquitous in the environment. These field studies, therefore, are helping to establish perspectives for the lifetime accumulation of artificial actinides such as plutonium.

None of these alpha emitters is considered hazardous to animals unless incorporated into biological tissues at high enough concentrations. Plutonium tends to concentrate in bones and in the liver if ingested with food; if inhaled, it will settle in the lungs and lymph nodes. But inhalation is not considered a major source of plutonium to animals on the contaminated floodplain because the soils are very moist, thus keeping airborne dust to a minimum.

Aquatic studies (by John Trabalka and Mary Anna Bogle) of fish in a radioactive-waste-settling pond indicate that americium and curium are more available to fish than plutonium. These aquatic and terrestrial field studies are helping reveal how the artificial actinide elements behave in ecological systems when compared with uranium and thorium.

Optimum Chlorination of Power Plants

Chlorine is routinely used in the cooling systems of power plants to control bacterial slimes and macroinvertebrate-fouling organisms. Macroinvertebrate-fouling organisms, such as mussels, can reduce water flow through the cooling system or block the condenser tubes. The slimes can form an insulation layer on the tubes. Both reduce the heat exchange across the condensers and result in a decrease in efficiency of electricity generation. But while chlorination solves some technological problems, it also poses some environmental ones. Fish kills have been linked to excessive releases of chlorinated effluent to waterways, and compounds formed by the reaction of chlorine with organic chemicals in water are believed to be potentially toxic and carcinogenic.

Finding the minimum level of chlorine required to protect cooling systems without inflicting unnecessary insults upon the environment and public health is a goal of Jack Mattice and colleagues at ORNL. They have focused on the residual chlorine compounds and chlorinated organics from the condenser cooling system. These researchers have used conventional methods to measure free-chlorine and combined-chlorine (chloramines) releases, then have studied whether these releases have toxic effects. There are no easy methods to measure chlorinated organics, but John Trabalka has studied the toxic effects on carp embryos and *Daphnia pulex* of 17 chlorinated organics identified by Bob Jolley of the Chemical Technology Division. He found that the concentration of these compounds that kills 50% of the test organisms is about 1000 times as high as the measured concentrations of chlorine released on the average from power plants. Says Mattice: "If the chlorinated organics tested are representative of the toxicity of these compounds and they are not bioaccumulated, then their release in power-plant effluents will probably not cause ecological problems. We plan to conduct studies to see if they are concentrated and magnified at various links in the food chain."

Mattice has proposed a model that takes into account site-specific dilution factors and allows higher limits for chlorine discharges (and hence higher chlorination levels) in cases where dilution is extremely rapid. This time/concentration curve, which is designed to help power-plant operators achieve safe levels of total chlorine residuals, has been accepted by Region V of the Environmental Protection Agency—*CK*

ENERGY DIVISION, April 24–25

State Gasoline Consumption

The federal government is currently formulating a contingency gasoline rationing plan. A final decision has not yet been made on whether to allocate fuel to individuals on the basis of average *national* or average *state* gasoline consumption rates.

An ORNL study conducted by David Greene and T. Patrick O'Connor may provide information on which to base sound rationing policy decisions. Entitled *An Investigation of the Variability of Gasoline Consumption Among States*, the document provides data which help to explain the wide variation observed in the state rates of highway gasoline consumption per household and per vehicle. The study, which covers the period 1966–75, was performed for the DOE's Office of Conservation, which participated on a task force charged with drafting a federal gasoline rationing plan. The ORNL study, however, is not a rationing plan, nor does it suggest what actions might be taken.

The study found that in 1975 the national average gasoline consumption was 753.9 gal per vehicle and 1388.8 gal per household, with state consumption rates ranging from 588.7 gal per vehicle for Pennsylvania and 864.5 gal per household for New York to 900 gal per vehicle for Arkansas and 2222 gal per household for Wyoming. Of the 14 southern states, 12 had household rates higher than the national average, and 13 had vehicle rates higher than the national average.

The analysis produced several conclusions which might have been expected. For example, state household gasoline consumption rates are less in urban than in rural areas, with severe winter weather, and with greater small car use. Consumption rates were shown to be greater in tourist areas and in areas with a large working-age population.

The ORNL study identified relationships among economic, demographic, and other variables and gasoline consumption. Some of the variables used were vehicle ownership rates, household disposable income, size of household, drivers per household, gasoline prices, and number of trucks in each state. The uniqueness of the ORNL gasoline-demand study stems from the analysis of the impact of factors, such as state spatial structure, climate, and types of economic activity on household consumption rates.

According to Green and O'Connor, it does not appear that differences in state gasoline consumption rates can be attributed to extravagant or frivolous gasoline use by the residents of certain high-consumption states such as Wyoming, New Mexico, and Texas. Instead, it appears that state consumption rates are the result of the complex interaction of environmental, demographic, and economic factors. These differences need consideration in developing any national conservation policy such as gasoline rationing, which will have differential impacts on the states.—*Betty Galyan Shields*

ENGINEERING TECHNOLOGY, May 18–19

Conversion to Coal by Industry

President Carter has proposed as part of his National Energy Plan that industry switch to burning coal to save our dwindling supplies of oil and natural gas. The industrial sector is a logical target for coal conversion because it is the largest user of gas, which is burned to supply steam and hot water for process heat. However, a study by Ted Fox indicates that several barriers discourage much of industry from switching to coal. Inhibiting factors include (1) the impracticality or impossibility of retrofitting a gas- or oil-burning boiler for coal; (2) capital requirements that are three to four times that of gas and oil facilities; (3) increasingly strict emission standards for coal-burning plants, and (4) lack of land at many industrial sites for stockpiling coal.

Concludes Fox: "The results indicate that, at least for the near term, wholesale conversion of industry from gas and oil to direct coal combustion is not forthcoming. The lack of substantial economic incentives, the increased risk due to intensified capital requirements, and the lack of a consistent environmental policy lead industries to postpone their coal-related energy decisions. Industrial boiler-fuel taxes and investment tax credits may help motivate some companies, but for the small- and medium-size users, the incentives are lacking, and the risks are too high."

Fox has examined two potential alternatives that may make coal conversion more attractive to industry. One idea is to establish area coal depots that could service a number of remote industries; such a repository for coal would provide coal handling, processing, and distribution services for dispersed users. A second alternative is to use a central steam plant that provides steam to a variety of industrial users. Says Fox: "The results indicate that these concepts provide additional incentives to convert to coal and appear promising for certain regions of the country."

Fuel Rod Simulator Technology

Laboratory interaction with private industry can be beset by obstacles, as illustrated in the case of the nuclear fuel-rod simulators. Several reactor safety experiments at ORNL require the use of highly instrumented electric heater rods which can simulate actual nuclear fuel rods in temperature profile and in power and temperature capability. Large-scale use of these fuel-rod simulators takes place at the Blowdown Heat Transfer–Thermal Hydraulic Test Facility, the Gas-Cooled-Fast-Reactor Core-Flow Test Loop, the Breeder Reactor Program Thermal-Hydraulic Out-of-Reactor Safety facility, and the Multirod Burst Test Program's experimental facility. Uniform performance and reliability are required in these fuel-rod simulators so that researchers can obtain accurate reactor safety information pertaining to heat transfer in reactor geometries for normal and off-normal conditions.

In the past, ORNL has contracted with companies to produce fuel-rod simulators that meet certain performance specifications (such as the ability to achieve a desired range of temperatures at the rod's surface during transient conditions). Unfortunately, fuel-rod-simulator quality and schedule requirements have not been sufficiently met by past procurement practices. Meanwhile, increased government commitments to out-of-reactor safety tests, more sophisticated analysis, larger bundle sizes, and more transient tests are increasing rod operational requirements.

ORNL has designed, fabricated, and tested some types of fuel-rod simulators that meet such performance requirements as heat-flux uniformity under transient conditions, accuracy of temperature measurement by thermocouples, the capacity to withstand thermal shock, and reliability. Therefore, the solution to the problem appears to be a form of technology transfer—that is, establishing and then issuing ORNL-set fabrication (not performance) specifications to selected industries from which the rods are procured. The industries under contract will then be given ORNL rod designs and fabrication methodology so that all performance requirements are met. According to Reg McCulloch, who works with a dozen researchers in ORNL's Fuel Rod Simulator Development Group, indications to date are that rod quality levels and production schedules can be achieved by further development of fabrication procedures and the continuing transfer of this technology to industry.

Heat Transfer Studies

Getting the most cost-effective energy out of hot underground fluids and thermal gradients in the ocean may require special heat exchangers designed to optimize heat transfer between sources and sinks. In their studies for geothermal and ocean thermal application, ORNL engineers are testing an assortment of heat exchanger tubes—some designed here and others procured from industry—with various working fluids. In particular, Rick Murphy and his colleagues in the Heat Transfer Enhancement Group of the Heat Transfer–Fluid Dynamics Section have concentrated on testing fluted tubes with ammonia as the working fluid for ocean thermal situations, and with fluorocarbons and hydrocarbons as the working fluid for geothermal uses.

Laboratory data show that large improvements in condensing heat-transfer performance are achievable using fluted tubes in place of smooth tubes. Specific performance values depend strongly on working-fluid composition, tube geometry, and heat load. ORNL engineers are now participating in field testing of heat-exchanger equipment at the East Mesa Geothermal Component Test Facility in southeastern California.

A primary accomplishment of the studies is the establishment of vertical smooth- and fluted-tube-condensing performance for eight candidate working fluids and ten different tubes. Future plans call for work in multicomponent condensation, fluted-tube evaporation, and heat-exchanger field testing. ORNL program manager for the work, sponsored by DOE's Geothermal Energy and Solar Technology Divisions, is John Michel of the Energy Division.—*CK*

BOOKS

A FORTRAN Coloring Book

by Roger E. Kaufman, The MIT Press, Cambridge (1977). 189 pp. + problems and index, $6.95. Review by B. K. Lyon.

Sample double-page spread from *FORTRAN Coloring Book.* (Reproduced by permission of MIT Press.)

This is not a coloring book. It is a FORTRAN primer, painstakingly set forth in elementary steps, and written in a style that can be called Wild Running Gag. Professor Kaufman, of the George Washington University faculty, claims to have tested this approach on "hundreds of M.I.T. students" while lecturing there. Their enthusiastic response, he declares, sent him to Washington. The response to the review copy in the *Review* editorial office has been a growing number of orders for the book, all from staff members who have suffered a need for FORTRAN in one form or another. The text and illustrations are printed and drawn by the author; there is no machine type in the book. As a result of the book's unique format, and as a result also of the author's peculiar talent, it reads like a comic routine at top speed; those who date back far enough will recognize the spirit of Spike Jones. Once you have leafed through it and have seen all the cartoons, a closer rereading will open for you the mysteries of programming in FORTRAN. To illustrate the flavor, an excerpt is displayed below. Irreverence pervades the book in everything but its commitment: to teach computer programming. That it does very well.

Here's the form of a typical Arithmetic If:

```
IF(EXLAX) 20,10,30
```

Between the parentheses is an Expression. This expression will make you go someplace immediately! If the expression is
Negative, go here → 20
Zero, go here → 10
Positive, go here → 30

In general, any sort of arithmetic expression can go between the parentheses, and any three statement numbers can go where I have 20, 10, 30. Just remember: the first statement number tells where to branch if the expression is (negative); the second, if it is (zero); and the third, if it is (positive). The same statement number can be repeated, if you want. For example,

```
IF(SUM+TOTAL) 100,15,100
```

would cause a branch to 100, unless the SUM plus TOTAL came to zero. Then the program would branch to statement 15.

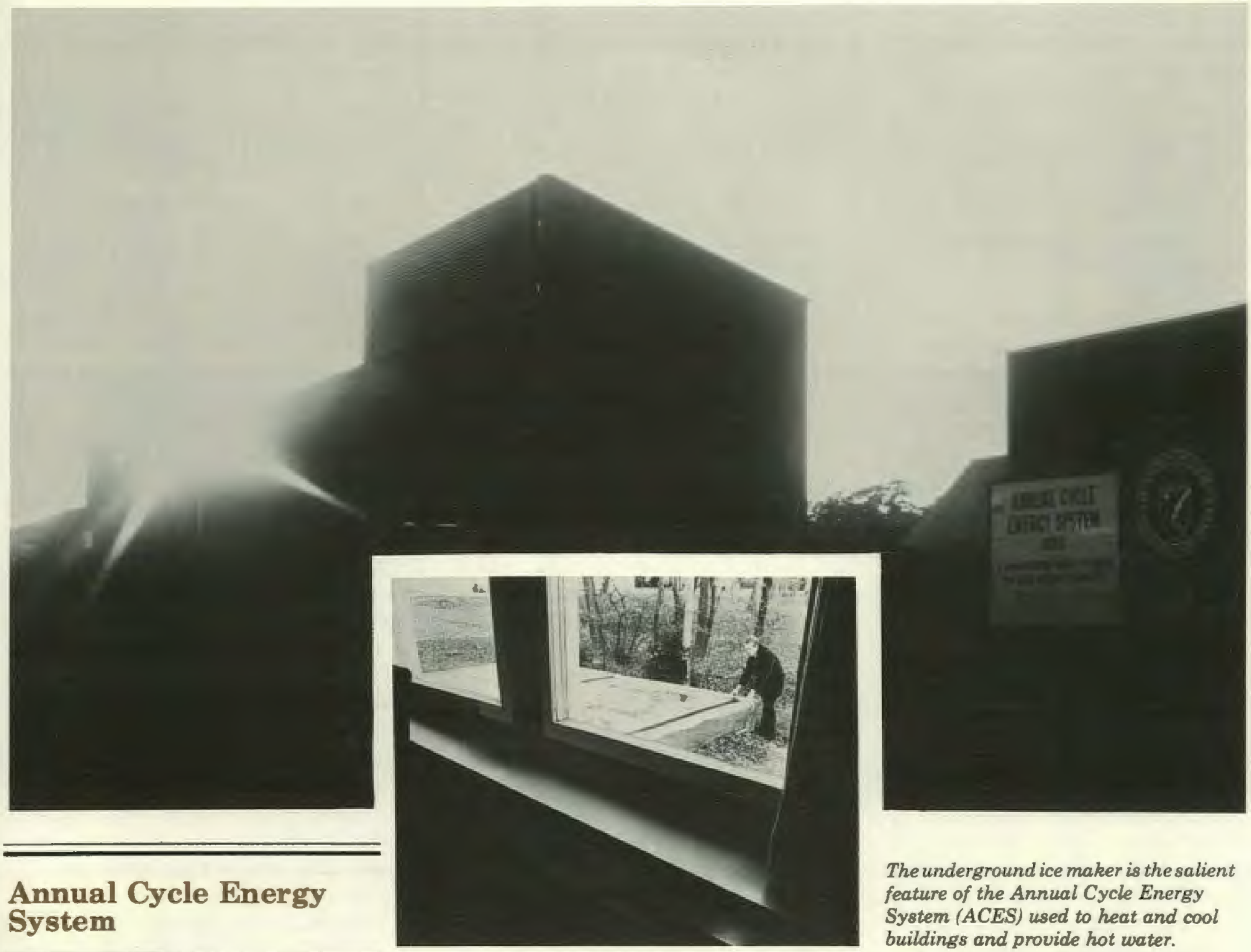
In a real-life situation, you might see a confusing program like this sequence of excerpts:

```
60 SPIRO = BOARD/WALK + PARK*PLACE
   IF(GRAFT-SQRT(SPIRO)) 30,75,60
   GOTO 50                  (Expression)
75 COLECT = 200.* DOLARS
50 PENSUN = 850000.*DOLARS
30 JAIL = LITLGY-NIXON
```

If the Expression has a Positive Value, the program jumps to statement #60

If the Expression has a Zero Value, the program passes the GO and reaches #75.

If the value of the Expression is Negative, however, the program jumps to JAIL= ..... it does not pass through the GO nor does it hit statement #75.



The underground ice maker is the salient feature of the Annual Cycle Energy System (ACES) used to heat and cool buildings and provide hot water.

Annual Cycle Energy System

Because the Annual Cycle Energy System (ACES) has inherent advantages in energy conservation for space heating and cooling and because it lends itself naturally to load management by power utilities, ACES is being adopted by the private sector while still under development by the Department of Energy through its ORNL program. Since the ACES technology was first developed in 1974/75, ORNL has received more than 1700 requests for information, and there are now some 30 ACES demonstrations in the private sector.

In the ACES, heat is withdrawn by a one-direction (heating only) heat pump from an insulated tank of water to heat space in wintertime and to provide domestic hot water year round. As heat is withdrawn from the water during the fall and winter, the water begins to freeze, filling the tank with ice by spring. During the following cooling season, the heat pump is not operated except to provide hot water as needed, but ice water from the storage tank is circulated through the cooling coil of the house's forced-air system, and essentially free air conditioning results. The only expenditure for energy is that needed to operate the water pump and air blower. By the end of the summer, the ice has all melted, and the water in the tank is once again available to provide energy for heating needs. Seasonal energy costs for heating and cooling and for producing hot water can be cut in half or more through the use of ACES, according to Bob Minturn, ACES program manager.

Transfer of the ACES technology to the private sector to date is occurring principally in the commercial, rather than in the residential, building market. According to Minturn, the primary reasons for this are that (1) packaged mechanical units, distributorships, and service networks do not yet exist for residential-sized systems, whereas commercial systems, conventional or otherwise, are custom designed and built, and an ACES presents no more problems in design, construction, and service than do other efficient systems; and (2) time-of-day rates and demand-charge structures available to most commercial users of electricity allow large building operators to save money by taking advantage of the load-shifting characteristics inherent in the ACES due to its storage features. On a seasonal basis, maximum loads can be shifted from summer to winter; on a shorter, even diurnal, time scale, loads for air conditioning can be shifted from day to night.

The ACES concept was first promoted at a workshop held at ORNL on October 29–30, 1975. Speakers at the workshop included Floyd Culler, former ORNL deputy director, and Harry Fischer and Gene Hise, ORNL staff members who are largely responsible for developing the concept. About 60 people participated in the workshop, including representatives from General Electric, Honeywell, Heatron, Refrigeration Systems, Climate Master Products, Halstead & Mitchell, Dole Refrigeration, Turbo Refrigerating, Bohn Aluminum & Brass, Refrigeration Research, and Commonwealth Edison Company.

This workshop, ORNL papers presented at outside conferences, and much publicity have kindled considerable industrial and utility interest in making, selling, and demonstrating ACES components such as icemaker heat pumps, solar heat exchangers, and ice bins. Some 20 companies have indicated an interest in commercializing ACES; at least three firms are now in the business of manufacturing ACES equipment. Refrigeration Systems of Evansville, Indiana, makes small icemaker heat pumps which are available for homeowners. Remcor Products of Chicago supplies ACES components for ORNL experiments, and Turbo Refrigerating Company of Denton, Texas, produces large ACES units for office buildings and other commercial structures.

Although no systematic effort has been made to discover all of the buildings now existing or under construction using ACES principles to save energy and money, Bob Minturn, of ORNL's Energy Division, and his associates are aware of more than 30 examples, many encouraged or funded by the utilities themselves. These range in size from 1600 ft^2 residences to office buildings exceeding 150,000 ft^2.
Private companies using or considering the use of ACES units include:

- *Detroit Edison Central,* for providing heat, cooling, and hot water from a centralized system to a cluster of new homes;
- *Georgia Power Company,* for its regional headquarters in Waycross, Georgia;
- *Getty Manufacturing Company,* for its factory and office building in Racine, Wisconsin;
- *Urban Development Corporation,* for its new apartment complex at Roosevelt Island, New York;
- *Holiday Inns,* for motels in areas subject to gas curtailments;
- *Philadelphia Electric Company,* for a nuclear power station visitors center.

The Veterans Administration Nursing Home in Wilmington, Delaware, uses a large ACES unit designed by Robert G. Werden & Associates of Jenkintown, Pennsylvania. Westinghouse Electric Corporation in Pittsburgh is evaluating ACES in Homelab, its experimental house.

Minturn is managing some DOE subcontracts, negotiated with industry by Union Carbide, Nuclear Division, to evaluate and demonstrate the ACES. One subcontract is with the Elliott-Lewis Corporation, which is procuring and installing an ACES unit in a house built in the Philadelphia area. Also under contract is Robertshaw-Control Corporation, which has developed a control system for the Philadelphia house to assure that the ACES installation is operated as efficiently as possible. Philadelphia Electric Company will install instruments to monitor operation of the ACES and will report results to DOE and other interested parties. ORNL is providing guidance to the industries involved and is making sure that the work is executed according to DOE plans. ORNL is also managing a subcontract with Honeywell, which is performing an economic analysis of ACES for three different building sizes in three different climate zones in the United States. The analysis will include comparison of ACES with conventional heating and cooling systems.

A number of utilities are testing or planning to test stored-ice systems and other ACES-like units to evaluate the potential of such systems for load management—the elimination of sharp increases in demand for electricity by storing energy and making greater use of off-peak power. Utilities known to be participating in ACES or ACES-like demonstrations are Baltimore Gas and Electric, Boston Edison, Consolidated Edison of New York, Georgia Power, Gulf States Utilities, Kansas City Power and Light, Kansas Gas and Electric, Metropolitan Edison, Ohio Edison, Pacific Gas and Electric, Philadelphia Electric Company, Public Service Company of Indiana, Union Electric Company, and Wisconsin Electric Power Company.

In this flurry of industrial activity all over the country in building and testing ACES units, ORNL researchers working in the DOE program continue to improve the efficiency, reliability, and range of applicability of this exciting concept. They are testing the concept at the ACES demonstration house near Knoxville, which used 35% less electricity than the control house (with resistance heating) on the coldest days of this past winter. Both researchers and industrial managers alike see ACES as an energy-efficient system whose widespread use could significantly reduce energy consumed for heating and cooling buildings, which accounts for more than one-fourth of the total energy used in the United States today.

ANFLOW

The rising national concern of the 1970s for energy conservation and environmental protection has provided new incentives for the development of innovative energy-saving technologies. However, protecting the environment and saving energy have not always gone hand in hand. For example, in 1972, Congress passed pollution control legislation which required secondary sewage treatment for communities by 1977, certain farms and feedlots during 1978, and industries in general by 1983. As a result, it was projected that the increased treatment of municipal and industrial wastes would require twice as much energy in 1980 as was consumed in 1975. Clearly, there was a need for new technologies that could reduce increases in costs and energy consumption.

A Norton Company worker installs sample taps and loads packing in the ANFLOW column during its construction at the Oak Ridge East End Sewage Treatment Plant. Microorganisms attached to the packing in operating ANFLOW systems digest organic wastes in liquid sewage pumped up through the column.

In response to the need for major near-term decreases in the energy intensiveness of contemporary technologies, ORNL has been engaged in the development and demonstration of a pilot-plant wastewater-treatment facility based on an anaerobic, fixed-film bioreactor. Called ANFLOW, this system departs from conventional sewage treatment schemes of the past two decades, which depended on an energy-intensive aerobic technology to supply oxygen to microorganisms used to digest organic wastes. The anaerobic microorganisms used in the ANFLOW system do not require oxygen, thus eliminating the need for energy-hungry aerators. The ANFLOW bioreactor uses a process of attaching microorganisms to stationary packing material and passing liquid wastes upward through the unit for continuous treatment by biophysical filtration and anaerobic fermentation.

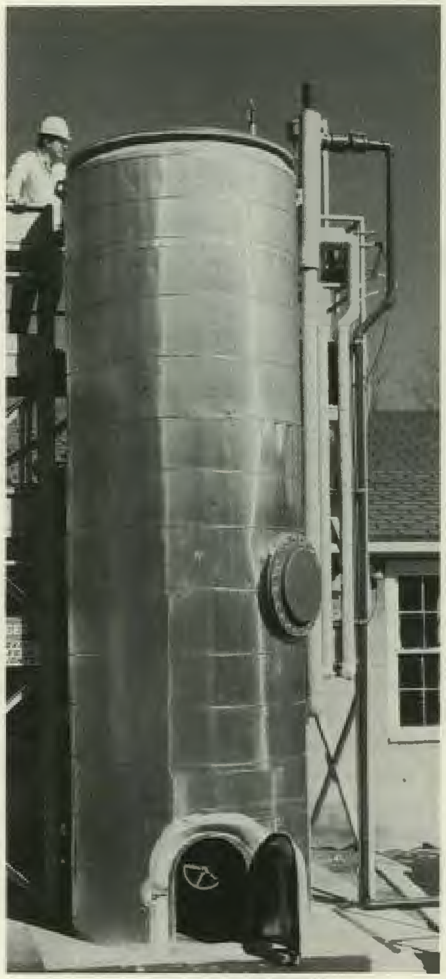
ANFLOW has been demonstrated in Oak Ridge, processing municipal sewage through a bioreactor designed to treat 5000 gal/day. The economic advantages of the process depend not only on the elimination of operating-energy requirements associated with aerobic-based technology but also on the significant decrease of sludge-handling costs incurred by conventional activated-sludge treatment systems. Methane can also be produced by ANFLOW systems.

With a view toward accelerating technology transfer, ORNL in a joint venture with the Norton Company of Akron, Ohio, designed an ANFLOW unit during the summer of 1976 and installed it that fall adjacent to the Oak Ridge East End Treatment Plant with the cooperation of the Norton Company and the City of Oak Ridge.

Industrial and municipal interest in the ANFLOW process has grown largely because of its record of stable operation, its potential ability for producing an effluent acceptable to the Environmental Protection Agency, and its potentially favorable economics. A preliminary economic evaluation reveals that ORNL's ANFLOW process is competitive with conventional sewage treatment schemes at plant capacities of 1 million gal/day or less. The savings are primarily related to operating costs but occur in capital costs as well. Representatives of industries and municipalities have learned about ANFLOW this year at the Symposium on Biotechnology in Energy Production and Conservation (sponsored by ORNL and DOE at Gatlinburg) and at a Fort Worth, Texas, conference where the potential use of ANFLOW technology in underground settlements was discussed.

Last spring, in a session exploring possible large-scale demonstration projects that would be jointly conducted by ORNL and the Tennessee Valley Authority, TVA committed itself in principle to building an ANFLOW system ten times the size of Oak Ridge's (50,000 gal/day) to be located at a trailer park built for workers at its Hartsville Nuclear Plant. Limited site preparations for the facility have been made, but DOE funding for such a project will depend on the final evaluation of ORNL's ANFLOW pilot demonstration.

The ANFLOW program, managed by Richard Genung, has allocated \$30,000 of its funds for a subcontract to develop a conceptual engineering design of a large-scale ANFLOW process. This subcontract has been awarded by a competitive bid process to Associated Water and Air Resources Engineers, Inc. (AWARE), of Nashville. This firm has been working with the ORNL staff in preparing a report to be used in appraising the feasibility of large-scale ANFLOW demonstrations such as the cooperative projects being explored with TVA.



Dan Million of ORNL examines the top of the ANFLOW column at the Oak Ridge East End Sewage Treatment Plant. ORNL provided engineering for the project, the Norton Company built the column, and the city of Oak Ridge prepared the site.

Jerry Case observes a signal from the alpha-counting apparatus (combining solvent extraction and high-resolution liquid scintillation) that measures trace amounts of uranium and other actinides.

Alpha-Counting Technique

Each actinide element emits alpha particles (helium nuclei) of a characteristic energy during radioactive decay. By counting alphas emitted per unit time, one can determine the amount of a specific element present. One of the better alpha-counting devices is the surface barrier detector, a silicon-based device which allows an electric current to pass through in proportion to the energy of each alpha particle striking it. However, the surface-barrier detector is used to count alphas emitted from nuclides deposited on stainless steel or platinum dishes through the use of a time-consuming electroplating technique. Although the resolution is the highest available, the counting efficiency is low; only about 5 to 35% of the alphas emitted enter the detector at appropriate angles. Furthermore, problems arise in the preparation of a suitable plate that is sufficiently free of interfering contaminants.

Jack McDowell and his colleagues in ORNL's Chemical Technology Division have developed an alpha-counting system combining solvent extraction and high-resolution liquid scintillation which minimizes some problems encountered by the surface-barrier counting of alphas. This ORNL system, which has been used to measure trace amounts of uranium, plutonium, thorium, and other actinides, offers these advantages: (1) a counting efficiency of 100%; (2) easier sample preparation in a much shorter period of time (45 min vs 16 hr for electroplating; and (3) improved reproducibility of results.

There is growing interest in this ORNL system. DOE is using it at Mound Laboratories, at Rocky Flats, and at Idaho Falls to detect and measure residual plutonium in soils as part of an effort to clean up radioactive wastes. Two corporations that make instruments have shown interest in the system, as has a California environmental analysis lab. Archeologists have considered using the scheme in dating ancient pottery, and medical researchers want to use it for studying actinide metabolism in animals (UT's Comparative Animal Research Laboratory is using it for this purpose). Phillip Morris is supporting research at ORNL to measure trace amounts of uranium, thorium, and polonium in tobacco; it is the contention of the cigarette company that the potential cancer hazard of smoking may stem from the presence of radioactive material in tobacco.

Currently, ORNL researchers are using this system for such tasks as measuring the quantity of uranium and thorium in phosphate fertilizers. The technique works like this: The fertilizer sample is dissolved in perchloric and nitric acids, and a series of chemical operations are performed to concentrate the nuclides in a 5-ml volume. Finally, the nuclide or nuclides are solvent extracted into an organic solution composed of solvent, extractant, energy-transfer agent, and scintillator; the solution is then placed in a high-resolution scintillation counter. The alphas emitted from the nuclide ionize molecules in the solvent (toluene), and energy from the stripped-off electrons is transmitted by the energy-transfer agent (naphthalene) to the scintillator, an organic compound whose electrons are easily raised to excited states in response to energy input. As the electrons relax and drop to lower states, the molecules emit light (photons). The flashes of light, which are in direct proportion to the alpha energies, are sensed by a photocathode. These photon pulses in turn are enhanced by a linear amplifier and displayed as an energy spectrum on a multichannel analyzer.

This ORNL system is capable not only of counting alphas but also of rejecting background beta and gamma radiation by pulse-shape discrimination.

Graphite Development

In 1971, ORNL initiated a program to develop an improved graphite for aerospace application. The work was performed under an interagency agreement with the White Oak Laboratory of the Naval Surface Weapons Center, and was specifically addressed to the problem of improved thermal shock resistance for missile nose-tips on reentry vehicles. The resulting new material has more than met the original objectives of the program: a twofold increase in thermal-shock resistance coupled with a significant reduction in wear from ablation or erosion.

In 1975, a contract was awarded by the Naval Ordinance Station, Louisville, Kentucky, to Great Lakes Research Corporation to work with ORNL to scale up this graphite and develop the manufacturing technology required for production. Present plans call for production to start in 1979. In addition to the fabrication process, the technology transfer has included quality control procedures and highly sophisticated quality assurance techniques on the final product.

The most unusual property of this graphite is its high strain to failure; that is, how far a sample can be stretched before it is pulled apart. This graphite exhibits a lengthening of 1%, about twice that of other graphites. This property, along with its extremely fine-grained structure, makes the material interesting in other commercial applications. Among these are metallurgical molds, substrates for semiconductors, electrodes for discharge machining, and vanes and throats for rocket engines.

The work is a natural outgrowth of ORNL's expertise. It rests on the Laboratory staff's extensive background in graphite for nuclear applications, reaching back to the days of World War II, which began with the now historic Graphite Reactor.

R. A. Cunningham, in the nondestructive testing laboratory, adjusts a specimen of the ORNL-developed, super-hard graphite for underwater ultrasonic testing.

Reactor Dismantling

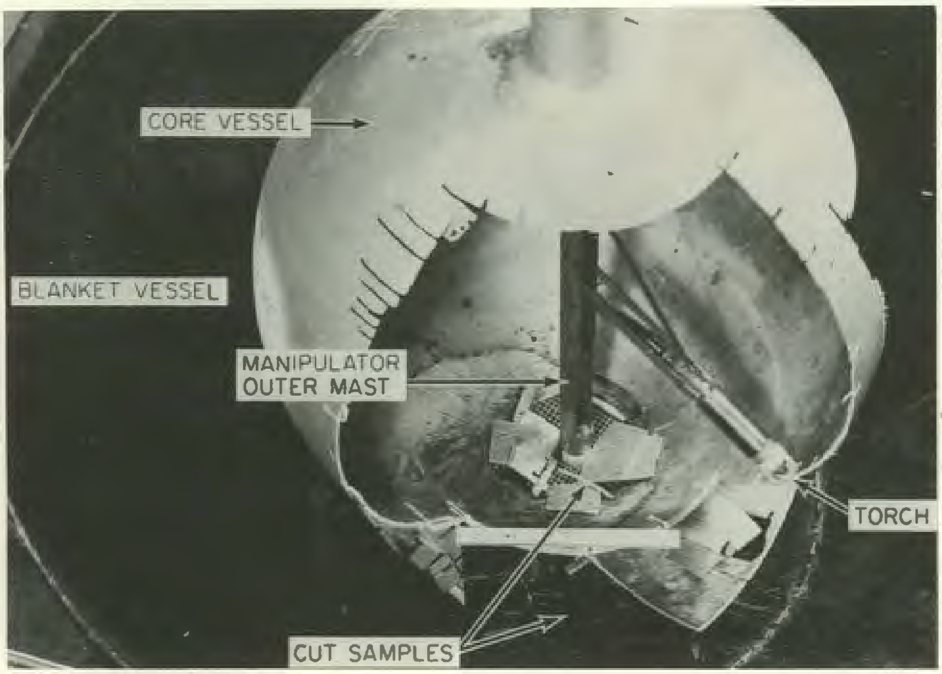
In 1972, ORNL engineers participated in the AEC project of dismantling the Elk River Reactor in Minnesota. ORNL provided the remotely operated tools and technology to remove and cut up all the reactor's radioactive internal components, the inner thermal shield, the reactor vessel, and the outer thermal shield, which was surrounded by concrete. All tools, including a 30-ft-high (10-m) remotely operated torch manipulator, were designed, fabricated, and tested at ORNL. Also, the Oak Ridge researchers improved the technology for underwater plasma-torch cutting during the Elk River project.

As a result of this experience, ORNL was engaged in 1975 by Atomics International, Inc., to act as engineering consultant for the dismantlement of the Sodium Reactor Experiment (SRE) and six other radioactive facilities located in the Santa Susana Mountains north of Los Angeles. Bob Blumberg of the Reactor (now Engineering Technology) Division, Clarence Wodtke of the Plant and Equipment Division, and Bob Beckers of the Engineering Division provided the consulting services. ORNL provided Atomics International with a complete set of drawings and specifications for the manipulator and the electrical circuitry as well as the actual control panel itself that was used for the Elk River effort.

In February 1975, ORNL engineers met with Atomics International personnel to discuss the application of the ORNL-designed plasma-torch manipulator for use in segmenting the SRE vessels and to review the proposed design modifications to the manipulator that would be required due to larger vessel sizes. At this and subsequent meetings, the ORNL representatives recommended that design criteria and application of the manipulator to specific cutting problems be investigated as thoroughly as practicable before the manipulator design is released for fabrication. Atomics International made drawing changes to adapt the manipulator for segmentation of the large SRE vessels and then handled fabrication in its own shops.

During this same period, Atomics International proceeded with the installation of a plasma-torch facility for use in determining operating limits of the torch for various workpiece configurations. AI demonstrated underwater plasma cutting at a full-size mockup of the SRE vessel cavity and then used the torch manipulator in the dismantlement of the SRE. Funding for ORNL's consultation work ended before the dismantlement was completed, but there had been sufficient interaction for technology transfer to take place.

Because the operating span of a power reactor averages 30 to 40 years, the clean decommissioning of nuclear plants will soon become an unavoidable fact of life. So far, the Elk River Reactor and the Sodium Reactor Experiment are the only ones that have undergone dismantling. The technology of remote maintenance developed at ORNL for operation and monitoring of, first, the Homogeneous Reactor Test, and later, the Molten Salt Reactor Experiment, placed the ORNL group in the unique position of being able to perform such exacting tasks. The transfer of this technique to Atomics International will place the expertise in the open market where it will be available to the public.



The lower end of the manipulator and torch in a mockup of the reactor core vessel.

Bonnie Talmi wrote this article at the end of her first year as information center coordinator for the Laboratory. After receiving her master's degree in library science from Columbia University, she worked for a year in the library of Cornell University, her alma mater. Talmi came to ORNL in 1972 to work for the Information Division in the Central Research Library and joined the staff of the Program Planning and Analysis Group in the fall of 1973. She is currently a candidate for an M.B.A. degree at The University of Tennessee, where she has also conducted courses in her field. Before assuming her present responsibility, Talmi spent three months on special assignment to ERDA headquarters, working with the Assistant Administrator for Field Operations on the design and implementation of a system for long-range institutional planning for ERDA's (now DOE's) multiprogram laboratories. Here she cites some of the ways that ORNL information centers interact with industry.

Bonnie Talmi, standing, shares a joke with secretary Brenda Roberts.

The Information Center As A Link With Industry

By BONNIE TALMI

The process of information transfer is broad and complex. It begins in the scientist's laboratory with the recording of experimental or theoretical conclusions and ends when that information is used to form new conclusions or to formulate practical applications. This transfer process includes the publication, collection, and organization of information; retrieval of materials and information; analysis and/or synthesis of many pieces of information; and, finally, the transfer of original, repackaged, or new knowledge to the end user.

Until the 1950s, publishers, secondary sources such as abstracting and indexing services, libraries, and "invisible" colleges—working groups of specialists—formed the basic organizational links that carried out these transfer functions. The rapid proliferation of funding for science after World War II and the exponential growth of scientific information severely taxed these traditional methods of organization and control and created great pressure in the system of scientific and technical communica-

How an Information Center Sparked New Research

In August 1976, Tom Connolly was glancing at titles of articles on microfilm when he spotted an interesting one: "Local Laser Annealing of Implantation-Doped Semiconductor Layers." This article, written by E. I. Shtyrkov and others, had appeared in the journal *Soviet Physics Semiconductors.* "Rosa Young should see this," thought Connolly, who is director of ORNL's Research Materials Information Center. At Rosa's request, Connolly had made a point of sending her any new information available on doping and annealing silicon. So Connolly activated the machine that prints out articles from the microfilm system in order to get the Russian article on paper.

Instead of dropping it in the mail slot as he usually does, Connolly personally delivered the article to Rosa and called her attention to it. Upon reading it, she and her colleagues conceived the idea of trying laser annealing on silicon used for fabricating solar cells. In discussing the idea further, they suggested that laser annealing might prove superior to the conventional technique of thermal annealing of silicon solar cells to remove the lattice damage introduced by ion implantation of the boron dopant. The idea culminated in last year's successful demonstration of laser annealing for making efficient solar cells, a technique that has sparked considerable industrial interest. Now, when Tom Connolly surveys the microfilm coming in, he reads about the research of Rosa and her associates, as cited in such prestigious publications as *Science* and *Physics Today.—CK*

Eric Lewis, George Dailey, and Don Wilkes confer in the Energy and Environmental Response Center.

tion. New ways were sought to utilize the new knowledge generated and to rationalize the technical information transfer system. In the early 1960s, the President of the United States appointed a panel to look at the situation at the national level and make recommendations. In 1963, the report of the panel defined the concept of the specialized information center as a "major key to the rationalization of our information system." The seed of ORNL's present program was planted when the oldest information analysis centers at ORNL came into being in the early 1960s.

Technology, broadly defined, is "the science of the application of knowledge to practical purposes." A key function of a technical information center is to collect, process, and disseminate information so that it becomes useful knowledge. In its philosophical foundation, then, an information center should be an institutional link in the technology transfer process. ORNL has 21 such centers, including ones in basic physical science data analysis, applied engineering, energy, environmental response, and social science data repository and analysis, among others. There are many examples of the interaction of ORNL technical information centers with the industrial sector as active participants in the Laboratory's commitment to technology transfer and utilization.

The U.S. industrial sector has a significant high-technology component with a broad spectrum of information needs. For many industries, ORNL information centers have played a role in the transfer of information from the research and development community to the industrial end user, then serving as communication channels to bring feedback to the technical community. Interactions range from input into the industrial R&D process as an aid

Jeffrey Klopatek and Janet Hyndman pore over maps developed for the Geoecology Project under Bob Burgess.

in understanding physical, chemical, or biological phenomena to direct input into the solution of practical problems, such as the development of an improved chemical process, or a piece of hardware, or the decision of whether to use a chemical additive based on knowledge of its genetic effects.

The ORNL Centers

The industries ORNL centers serve are largely those in the high-technology area. The Nuclear Safety Information Center (NSIC), directed by Bill Cottrell and Joel Buchanan, provides current information on reactor safety developments to the nuclear industry, including such reactor vendors as Westinghouse and Kaiser, utilities such as Florida Power and Light, and architect-engineers such as EG&G and Bechtel. The Radiation Shielding Information Center (RSIC), directed by Betty Maskewitz and Bob Roussin, serves generally the same community with the latest computing technology and data libraries for their use in shielding calculations and design.

The Research Materials Information Center (RMIC), directed by Tom Connolly, uses its state-of-the-art knowledge of high-purity research materials, to serve the optics (especially laser), electronics (especially semiconductor), and communications industries. Eastman Kodak, Bell Labs, IBM, and General Electric are some of the users of RMIC. Under the direction of Gerry Ulrikson, various centers in the Information Center Complex (ICC) such as the Toxicology Information Response (TIRC), Environmental Mutagen (EMIC), and Environmental Teratology (ETIC) information centers, and the Toxicology Data Bank (TDB), specialize in biomedical effects of chemicals. These constitute a valuable resource for the chemical and pharmaceutical industries including major companies such as Dow Chemical and Hoffman-LaRoche. The Biomedical Computing Technology Information Center (BCTIC), also directed by Maskewitz with Bill McClain as assistant group leader, and the mutagen and teratology centers, under John Wassom's direction, have considerable interaction with the medical community, including private physicians and hospitals. In mutagenesis and teratology, the centers have long-established, international reputations bringing inquiries from abroad, including from such hospitals as St. Bartholomeus in London and Western General in Edinburgh.

The Package

Information centers transfer technical knowledge in three general forms: standardized products, customized products and services, and participation and exchange activities.

Standardized products are those that have value to a large segment of the center's technical user community. Once produced, they are made available for wide and continuing distribution. Publications, specialized data bases, and computer-code packages are the significant forms of such products from ORNL centers. Publications include technical reports, state-of-the-art reviews, bibliographies, newsletters, handbooks, data tables, and journals.

The *Nuclear Safety Journal,* edited by Bill Cottrell, has been a key channel for the transfer of safety information with its review articles on recent findings and developments in the field. Reactor Shielding, Biomedical Computing, and the Controlled-Fusion Atomic Data Center put out newsletters which act as key communication links within their respective user communities. They announce new technology developments and offer news about their fields of interest. In the field of biomedical and environmental effects of chemicals, greater federal attention to and regulation of industry has increased the need for state-of-the-art reports on chemical effects. The Health and Environmental Studies Program, under the coordination of Anna Hammons, is producing a series of state-of-the-art reviews on environmental effects of pollutants, including arsenic, asbestos, benzidine (an amine used in dyes), beryllium, cadmium, chromium, cyanide, and fluoride. In a joint effort between D. J. Wilkes's Energy and Environmental Response Center and Helen Pfuderer's Ecological Sciences Information Center, a two-volume information overview entitled *Environmental, Health, and Control Aspects of Coal Conversion* was recently completed. Both this and the environmental reports are much in demand by industrial firms which need to keep abreast of the developing information. Regulatory agencies and policy-makers are also keenly interested in these reports and, in fact, the Environmental Protection Agency sponsors the Health and Environmental Studies Program.

In addition to publications, there are two nonprint products through which our information centers serve the industrial sector. The computer-code and data packages, key products of Biomedical Computing and Radiation Shielding, provide their users with the most up-to-date computer programs and nuclear data compilations relevant to solving their biomedical or shielding problems. These two centers offer what they call an "open-code package," whereby the user is expected to provide feedback on his experience with the code and add to it any new developments, such as its implementation on a different type of computer, or to point out any weaknesses in the program. The industrial users are of particular value here because they test the codes through practical application to real-world problem solving and provide feedback to the centers.

Jan Joness, ORAU summer student, uses a planimeter to gather information from a map that will be put into the Geoecology Data System.

Computer Retrieval

The development and maintenance of specialized computer data bases is often a key activity of an information center. These data bases support many center services and often serve as major products in themselves. Many of these bases are made available to industry through published versions, through response to direct inquiries of the centers, through DOE's RECON, and, more recently, through the National Library of Medicine's TOXLINE. For example, ORNL bibliographic data bases that are available through RECON and used by industry are the Environmental Mutagen Information File, Energy R&D Projects File, Nuclear Safety Information Center File, Radiation Shielding Information File, Radiation Shielding Codes, Environmental Teratology File, and Nuclear Structure References.

The Toxicology Data Bank is a computerized file of biological interactions and effects of selected chemicals, including pesticides, food additives, pharmaceuticals, and industrial chemicals. It will shortly be accessible through TOXLINE. The chemical and pharmaceutical industries have shown considerable interest in using this file to help them in their product development and regulatory compliance activities.

Special state-of-the-art, computer-readable, data libraries compiled by RSIC are another noteworthy example of technology transfer to industry. RSIC, through the efforts of its staff and other Laboratory experts, takes data, mainly from the evaluated nuclear data file (ENDF/B) and processes it through computer-code systems developed at Oak Ridge to produce libraries that offer easily accessible information regarding the probabilities of specific behavior of neutrons in different materials. These libraries provide data relevant to candidate shielding materials and can be used by the nuclear industry to solve radiation-analysis and shielding-design problems. The Nuclear Data Project, a basic physical science data center, reviews the primary literature and produces some of the critically evaluated data that goes into the ENDF/B file. At the other end of the transfer process, RSIC receives feedback from the industrial users on its code packages. Thus, in this example, we see the full cycle in technology transfer where the R&D reported in primary literature is processed by a basic science information center for use by an applied information center to provide a code package which solves an industrial problem. The industrial feedback then completes the cycle.

Information on Demand

The second general product area is that of customized pro-

Author Talmi and Don Wilkes go over some data at the Energy and Environmental Response Center.

ducts and services. These are tailor-made responses to an individual user's request. Customized literature searches, query-response services, selective dissemination of information programs, and consulting services are the key forms of packaging for customized services to industry.

For instance, the Toxicology Information Response Center, directed by Helga Gerstner, specializes in customized literature searches. TIRC is under the sponsorship of the National Library of Medicine to provide toxicological information about a variety of chemical classes to all individuals on a cost-recovery basis. Gerstner reports that over 13% of the center's use comes directly from private industry, mainly from chemical companies. Indeed, TIRC conducts as many as two major literature searches a week. Typical of the searches that have been requested are "Cyclohexanols: Toxicity in Animals and Man," or "Nickel—Air Concentrations in Work Environment." In addition to in-depth literature searches and other major literature support programs, TIRC also provides factual data on chemicals, such as lethal dose values, lethal concentrations, and chemical structures. TIRC responds to requests for data, such as the structure of Direct Red Dye #39, or the toxicity of iridium.

Working closely with TIRC within the ICC are the Environmental Mutagen and Environmental Teratology centers. Industry (including doctors and hospitals) receives about 18% and 45% of their services respectively. An interesting development which has most recently begun to emerge is the impact of the passage of the Toxic Substances Control Act on these centers' interaction with industry. The resulting increase in regulatory and reporting requirements on the chemical industry is felt heavily in these information centers. Much staff time is now devoted to telling industrial requestors where the sources of biological effects information are, how they can be accessed and who the experts are in the field.

Another center providing valuable customized services to industry is the Research Materials Information Center. About 15% of the inquiries to this center come from industrial users. RMIC's specialty is information on the preparation and properties of high-purity inorganic materials. The center has developed a resource file that tells where such materials are available or, in the event of unavailability, how to prepare them. Typical questions concern the properties of a given material or, conversely, what material fits certain property requirements. Connolly tells of one recent case in which a company was using gallium arsenide as a laser modulator. The gallium arsenide was supplied to them as an encapsulated component. Without any noticeable change in the optical measurements, the devices ceased to operate efficiently as modulators. The company turned to RMIC for information that could help determine the cause of the problem. In response,

Cathy Fore applies herself to the mountains of input at the Ecological Sciences Information Center.

the center provided information on effects of stoichiometry, trace impurities, and crystal growth methods on the optical properties of gallium arsenide.

An example of customized query-response is the service the Nuclear Data Project provides to industrial users who need the most up-to-date, critically evaluated, radioactivity data. In the last year, the Nuclear Data Project has had requests from hospitals, utilities, instrument companies, and consulting firms for data in applications as diverse as detector efficiency, clinical medicine, reactor design, and standards efforts.

Interchange

As for that area of interaction with industry encompassing participation and exchange, ORNL information center personnel have served on standards development committees, have organized technical programs for professional society meetings and seminar-workshops, and have participated in foreign technology-exchange programs.

Because standards have direct impact on the industrial community and the data on which standards are based often come from the R&D community, information flow and interaction among these communities, and between them and the promulgators of standards, are crucial. Also, because standards requirements should represent state-of-the-art knowledge on a given topic, the production of a standard is itself a form of technology transfer. With the support of ORNL centers' resources, information center personnel have played key roles in developing standards in their areas of expertise. For example, Maskewitz serves on the ANS Standards Subcommittee on Mathematics and Computations (ANS-10); and Dave Trubey, also of RSIC, chairs the ANS Committee on Radiation Protection and Shielding (ANS-6).

With regard to international technology-exchange programs, information centers routinely seek to cover all of the world's literature in a field. In keeping with this goal, NSIC is the designated Nuclear Regulatory Commission repository and distributor for NRC's foreign reports exchange on reactor safety research with the United Kingdom, France, Germany, and Japan. NSIC is responsible for evaluating, translating, and disseminating the information in these documents to the U.S. nuclear community.

RSIC has found that seminar-workshops are particularly effective for transferring computing technology and periodically sponsors workshops where computer-code developers teach details of operation and theory to prospective industrial users.

A final example of an information center program that engages in participation and exchange activities is the Regional and Urban Studies Information Center's (RUSTIC) designation as a National Bureau of the Census Summary Tape Reprocessing Center. This status means that RUSTIC receives U.S. Census tapes and, in return, is expected to provide assistance, on a cost-reimbursable basis, to those who need access to and use of the tapes. Firms such as E. I. DuPont DeNemours, Gibbs & Hill, Inc., Aerospace Corporation, and International Systems, Inc., have used this service.

All these activities and interactions are only a few examples of the interaction between ORNL information centers and industry. In 1963, the report of the President's Science Advisory Committee stated that "transfer of information is an inseparable part of research and development. All those concerned with research and development—individual scientists and engineers, industrial and academic research establishments, technical societies, Government agencies—must accept responsibility for the transfer of information in the same degree and spirit in which they accept responsibility for research and development itself."

ORNL's technical information center program traces its beginnings to the recommendations which follow this opening statement of the report. Fifteen years later, ORNL centers have indeed become a significant institutional link in technology transfer.

lab anecdote

Cutie Pies and Other Low Grid Currents

When Alfred Nier made a precision measurement of the ratio of U-235 to U-238, his success depended on a new electrometer tube of high gain and extremely low grid current, the FP54, which could measure 10 electrons per second. It was larger than the usual radio tube and was made in such small numbers that it was produced at a bench and not on an assembly line. When I briefly used a Nier mass spectrometer, I had to replace an FP54 of serial number 172 with one of serial 942; the gaseous-diffusion business had multiplied the demand for mass spectrometers. There was a story going around that the production of the FP54s was seriously cut back when one of the two women who made them at the bench had marital difficulties.

The Victoreen Company contracted to make a smaller electrometer tube for the Manhattan Project. In 1944, they delivered the peanut-size VX32, and Mr. Ballou in the instrument shop promptly made a hand-held ionization meter, which he named "Cutie Pie" for his wife. The design of that meter has hardly changed in the 34 years since, and they are still in use. Those who didn't like the name called it the CP meter. P. R. Bell made a meter of the same design, but half the size, which he named "Sweetie Pie."

Several years later, P. R. Bell used the miniature tubes then available to make a "pocket screamer," an even smaller radiation meter. With the coming of transistors, Cas Borkowski could design a meter about the size of a penlight which could light a red lamp and chirp like a canary when the dose rate was scarcely greater than the natural background rate. It was several years later that the accumulated dose, and not merely the dose rate, could be measured with transistorized meters.

Don Cowan, when he was in charge of public information for ORNL, learned of the sensitivity of the penlight meters on a plane flight. He fell asleep with several of them in his briefcase. The stewardess had difficulty finding the canaries she thought some one had brought aboard. It seems that at 30,000 ft, the natural radiation is nearly twenty times as great as that at sea level, and the meters he carried were set for warning at sea level.

—Herbert Pomerance

Testing Coatings for Nuclear Use

The paint used to coat the inside of a nuclear-reactor containment vessel is subject to some fairly exacting specifications. It must withstand high humidity, cumulative radiation dosage, and elevated temperatures for the design life of the facility. The surface must be easily decontaminable and of sufficient durability to withstand projected conditions of certain design-basis accidents (DBA). The nuclear-coatings testing laboratory in the Analytical Chemistry Division is the only independent laboratory capable of conducting radiation stability, decontaminability, and DBA tests that satisfy the quality assurance programs of the nuclear industry, and that also meet the requirements of the Nuclear Regulatory Commission.

Simulation in a short time of the cumulative gamma-ray dose imposed over 40 years of reactor operation can be done by inserting the sample into the target space of a spent-fuel assembly from the High Flux Isotope Reactor. This exposure represents more closely than does an isotopic source the types of radiation found in a reactor. The HFIR operates under water, where the spent fuel is also set to cool. The assembly, consisting of concentric cylinders of enriched uranium in layers of aluminum, has an open cylindrical space in its center, approximately 76 cm long and 10 cm in diameter. Samples of coated metal and concrete are exposed to the fuel element in this hole for several measured lengths of time, simulating exposures that

Chips coated with the materials being tested are dropped through this tube into the empty target area of the cooling HFIR fuel element for exposure to reactor-like radiation.

range from 1×10^7 to 5×10^{10} rads. The ambient temperature of the circulating water around the sample is about 60°C. The design of the test is such that the sample is not rendered radioactive, permitting the subsequent DBA and decontamination tests to be performed.

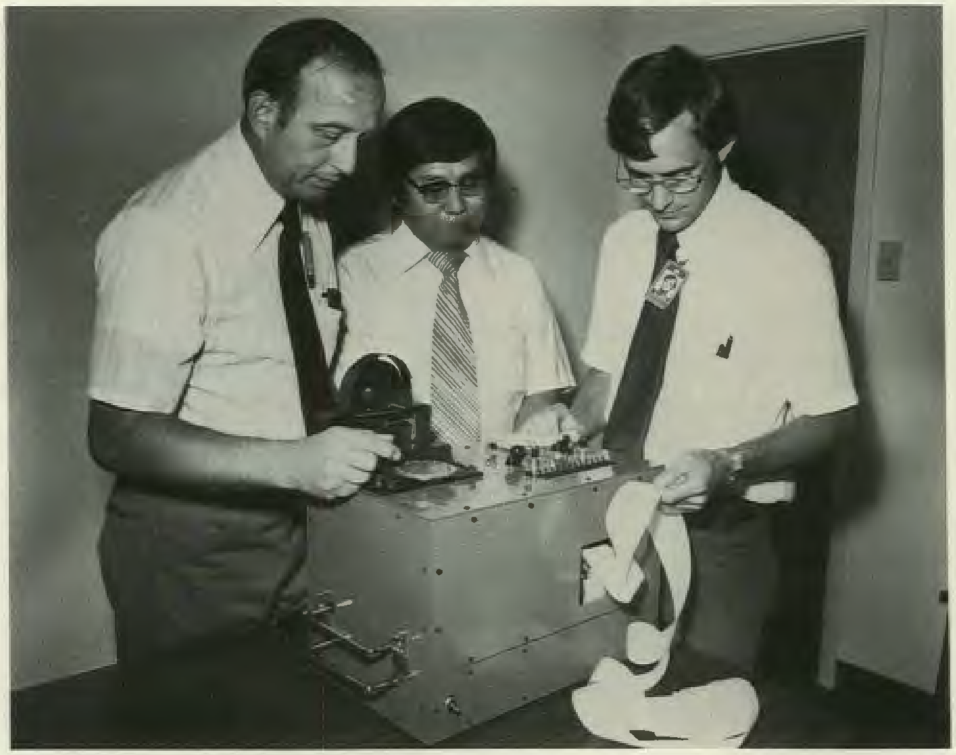
The DBA simulation is enacted in a pressurized chamber in which the sample is sprayed with hot (180°C) recirculated solutions of boric acid at pH 9.5. The test is conducted on both irradiated and nonirradiated specimens over a period of seven days under controlled temperature and pressure changes.

The ability of the coatings to be decontaminated is tested under three conditions. The surface is contaminated with a drop of solution containing fission products which give it a minimum of beta-gamma activity of 5×10^6 disintegrations per minute. It is then air dried. Thus contaminated, the sample is subjected to three cleansing procedures: It is immersed in ordinary tap water for a period of time and air dried; it is subjected to an acid solution at room temperature; and, finally, it is washed with a hot (80°C) solution of the same acid.

Samples, prepared according to standardized procedures, come to ORNL for testing only after the manufacturers have reached a contractual agreement with the Department of Energy. The confidential reports of results prepared here for the manufacturers are acceptable throughout the nuclear industry as the basis for testing compliance. This compliance must be met before a manufacturer can bid on any primary containment-coating contracts. In the five years this testing laboratory has been in operation, it has tested over 10,000 samples. Approximately 30 paint manufacturers are currently under contract for continuing testing at ORNL.

The testing facility is unique. Recently, Carborundum Company, in Niagara Falls, asked to have certain of its products tested for radiation stability to satisfy NRC standards, having been directed to ORNL by NRC as the only place where such testing can be done with the necessary high level of radioactivity within the desired time scale.

John Mrochek (left) and Martin Bauer (right) of ORNL examine a prototype of a portable centrifugal fast analyzer (developed at ORNL) that was built by Electro-Nucleonics, Inc., under the direction of Nakwon Cho (center).



Zonal Centrifuges and Centrifugal Analyzers

The commercial manufacture and marketing of zonal centrifuges is a $10 million/year business, and annual sales of centrifugal fast analyzers total about $50 million. The original designs for both of these devices were conceived in the late 1960s by Norman Anderson, then director of ORNL's Molecular Anatomy (MAN) Program and now a staff member at Argonne National Laboratory. The lag between the initial concept and commercial adaptation of both developments was about five years.

The ORNL-developed zonal liquid centrifuge was first used commercially in 1967 to produce the ultrapure flu vaccine, Zonamune. Today, zonal centrifuges are manufactured by Electro-Nucleonics, Inc., and are sold to domestic and foreign vaccine-manufacturing industries, which centrifuge their vaccine materials to remove impurities that could cause harmful side effects in patients. Nakwon Cho, ENI's Oak Ridge representative, says that zonal centrifuges are a "big moneymaker for ENI" and noted that the company has a large overseas market, particularly in Russia, Japan, Czechoslovakia, and England, where socialized medicine programs prevail.

Separation of the impurities from vaccines is accomplished by spinning them in the centrifuge, a high-speed rotating device which causes particles to be forced outward from the center of rotation by centrifugal force. Particles are separated according to their density or size and then are collected. The most familiar example of centrifugation is the cream separator, which separates fresh milk into two fractions—lighter fatty cream and the denser, skim milk.

In 1968, Anderson invented the first centrifugal fast analyzer, dubbed GeMSAEC in honor of the government agencies that funded its development. One of ORNL's most famous innovations, this device revolutionized the speed, accuracy, and sensitivity with which medical diagnostic tests and other analyses can be performed. Three commercial versions of the GeMSAEC are being manufactured by Electro-Nucleonics, Union Carbide, and Aminco (American Instrument Company).

Hospitals and clinical laboratories purchase commercial GeMSAECs to measure certain constituents in urine and blood, such as various enzymes, total protein, glucose, and triglycerides, in order to identify malfunctions of the liver, kidney, and heart. The first-generation commercial devices were quite large, involving a centrifuge connected to a spectrophotometer and computer. Nowadays, there are more compact centrifugal analyzers on the market. Electro-Nucleonics sells the GEMINI, a microprocessor-based analyzer with a 20-cuvet rotor. ORNL's second-generation centrifugal analyzer—a miniaturized [1 ft^3 (28 liters)] analytical module coupled to a relatively large minicomputer—has recently been made available commercially by Instrumentation Laboratories, Inc., which is marketing it under the name Multistat III MCA. ORNL's

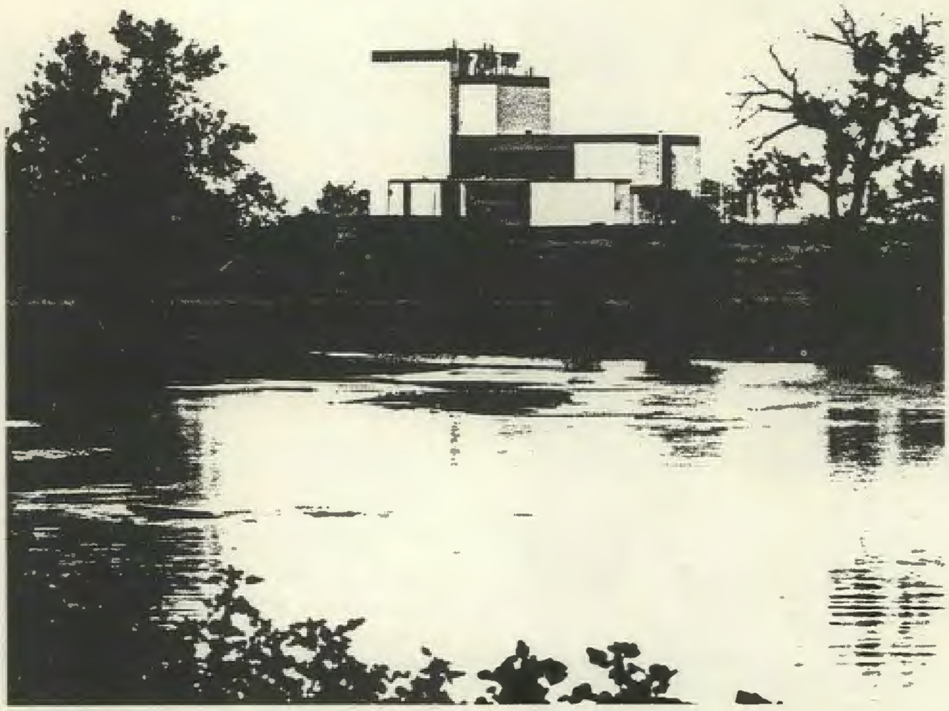
Laboratory technician Evelyn Hurst adjusts the GeMSAEC centrifugal analyzer used in the Health Division at ORNL.

miniaturized centrifugal analyzer, developed under the leadership of Chuck Scott, is in use at the National Institutes of Health in Bethesda, Maryland; the National Center for Toxicological Research in Arkansas; NASA's Johnson Space Center in Houston; the Human Genetics Department of the University of Michigan; Albert Einstein College of Medicine in the Bronx, New York City; and in the ORNL Health Division.

Electro-Nucleonics has exhibited interest in developing a commercial version of an even more compact machine devised at ORNL by Scott, John Mrochek, Martin Bauer, and Richard Genung—the third-generation Portable Centrifugal Fast Analyzer. Like the initial GeMSAEC prototype, this device last year received an IR-100 Award. Weighing only 55 lb (25 kg), this new machine takes advantage of improvements in electronic circuitry and computer technology. It is small enough to be carried into remote or rural areas by mobile vans and may be operated from a battery pack; it is versatile enough to be used for routine analyses of minute quantities of blood serum and urine, for typing of blood at a patient's bedside, for measuring concentrations of environmental pollutants such as phosphates and sulfates, and for clinical monitoring of astronauts in space. In fact, NASA is having the instrument fabricated to evaluate it for future space-shuttle flights. In the meantime, versions of the Portable Centrifugal Fast Analyzer have been built by ORNL for use by the Environmental Sciences Division, the Research Triangle Institute in North Carolina (under a contract with the National Institute of Environmental Health Sciences), and the University of Michigan.

Centrifugal analyzers make use of the spinning motion imparted by a centrifuge in two ways: The rapid acceleration mixes a series of samples and reagents (varying from 16 to 20 of each) simultaneously, and the rotational motion moves all sample compartments past a stationary optical monitoring point where the transmission of various components of the light beam through the sample compartments is monitored. The variation of light transmission with time (corresponding to measurement of a reaction rate) or the absolute amount of light transmitted may be related to the amount of an enzyme or chemical component present in the sample. The computer acquires light-transmission data from each sample and performs the necessary calculations to convert these measurements to either a rate (for an enzyme) or an absolute amount (for a chemical). Elevated amounts of certain enzymes can indicate organ malfunction or damage without the need for exploratory surgery.

Industry and Gas-Cooled Reactors



The Fort St. Vrain Nuclear Generating Station, built for Public Service Company of Colorado by Gulf General Atomic, is a high-temperature gas-cooled reactor now in operation.

ORNL has been involved in gas-cooled reactor technology for many years, having participated in important developments for the High-Temperature Gas-Cooled Reactor (HTGR) and the Gas-Cooled Fast Reactor (GCFR) programs. In the United States, two HTGRs have been operated commercially: the Peach Bottom, a small, experimental power reactor that has been decommissioned; and the Fort St. Vrain Reactor, now approaching full-power operation. General Atomic Company has temporarily withdrawn from the reactor market, but design and development of the HTGR is continuing under the leadership of Gas-Cooled Reactor Associates, a utility organization. Lacking sufficient separate funding to accomplish needed research, development, and demonstration independently, the GCFR has leaned heavily upon LMFBR and HTGR technology.

HTGR Base Program

This ORNL program supports such HTGR concepts as work in the technology of fuels, structural materials, graphite, prestressed-concrete reactor vessels, reactor chemistry, and reactor design assessments. Initial development of the reference fertile particles for all HTGR concepts, a thorium dioxide kernel with carbon coatings (and sometimes silicon carbide coatings), was done at ORNL. And, although General Atomic used a sol-gel method different from ORNL's original technology, a great amount of the thorium oxide–particle technology is based on ORNL-developed processes and equipment. In addition, all of the alternative fuels for the HTGR are based on either sol-gel technology or the weak-acid resin-derived particle, the latter of which is also an ORNL-originated development. Many contributions have also been made in coating technology and in fuel-rod process development. In fact, the first fuel rods for loading into graphite blocks were made at ORNL after recognition of the possibility that loose coated particles might not give acceptable performance in an HTGR. These contributions have resulted in reduction of costs and enhancement of fuel performance.

A cooperative program with General Atomic relative to surveillance work on Peach Bottom Reactor driver elements provided valuable data for development and verification of fission-product-migration models. The Peach Bottom driver elements were examined at ORNL. Included in the postirradiation examination were dimensional inspection, metallography, and detailed gamma spectroscopy to quantify fission-product profiles in the graphite bodies of the driver elements. These data were published in reports for use by GA staff to develop and verify the models used in a number of computer codes.

Gas-Cooled Fast Reactors

ORNL has been involved in the technology of the GCFR for a number of years, developing and transferring technology to General Atomic Company. ORNL has provided fuel pins for irradiation tests in the EBR-II and has built and conducted instrumented irradiation tests in the Oak Ridge Research Reactor (ORR). These tests have formed a substantial part of the data base for assessment of fuel performance for GCFRs. In recent years the Laboratory has become more involved in three areas of technology: the Core-Flow Test Loop (CFTL), which is a major program element for determining the detailed data needed to design and assess the probable performance and safety characteristics of GCFRs; the GCFR shielding; and the Prestressed-Concrete Pressure Vessel (PCRV). Principal contributions to the PCRV include design improvement to the reactor vessel itself and to various components, such as plugs and instrumentation. Major technical contributions for the CFTL have included development and provision of manufacturing methods for fuel-rod simulators and high-temperature, high-pressure helium circulator development. In shielding, ORNL is assisting General Atomic in reactor core design by performing complex shielding calculations as well as experimental studies to determine the adequacy of analytical methods. Reactor-physics studies are also being performed for heterogeneous core concepts. The results of the above studies are transferred to General Atomic for their use in providing a workable GCFR system for power production.

Fuel Recycle

For a number of years, ORNL has led the fuel-recycle program with principal participation by General Atomic and Allied Chemical Corporation; if fuel recycle is ever sanctioned or required, the commercial operations will reflect developments already completed at ORNL. The program includes development of all processes, equipment, facilities, and products required to recycle HTGR fuel and to leave the waste in a form useful for fixation. All flowsheets for reprocessing and refabrication of highly enriched uranium-thorium fuel for the HTGR are essentially proven through cold-engineering work.

International Aspects

The Gas-Cooled Reactor programs at ORNL are also involved in the transfer of technology to participants in the U.S./West Germany Umbrella Agreement in the field of Gas-Cooled Reactors. This transfer takes place through the development and completion of Project Work Statements, which address a specific technology area. Examples include a cooperative program between ORNL and KFA Jülich in the irradiation testing of graphites for HTGR use. ORNL is also assisting EIR, a national laboratory in Switzerland (and a cosigner of the Umbrella Agreement), in the design of GCFR shielding experiments. Further, cooperative Project Work Statements between ORNL and KFA Jülich are being developed in a number of HTGR fuel recycle areas, and in HTGR fuel development and HTGR materials.

Dynamic Membranes for Processing Wastewater

Equipment for use of dynamic membranes, developed at ORNL in 1965 as part of the research effort on desalination, is now being fabricated by industry and sold to industrial installations needing the process for removing pollutants and recovering valuable chemicals from wastewater. For example, a J. P. Stevens plant in Clemson, South Carolina, is using a full-scale dynamic-membrane system for recovering expensive polyvinyl alcohol from rinse water used in washing the sizing from textiles. This pollution-abatement and chemical-recovery system consists of UCARSEP, an ultrafiltration system based on porous carbon tubes made by Union Carbide, which have also been sold for oil and water separations necessary in treatment of effluents from phosphating of metals prior to painting. The possibility of large-scale use of these units to process whey streams in the dairy industry seems excellent at this time.

The modules and membranes were developed for specific applications by the Union Carbide staff at Tarrytown. In 1975, UCARSEP won a Merit Award in the Kirkpatrick Achievement Awards competition sponsored by *Chemical Engineering* magazine. In the description accompanying the award, ORNL was acknowledged for pioneering the membrane technology, which was developed by Kurt Kraus, Josh Johnson, and others of the Water Research Program.

In a current consolidation of new ventures of Union Carbide, sale of the UCARSEP business to other companies is under serious consideration. In the meantime, other companies are entering the dynamic-membrane manufacturing field. They include the Selas Corporation in Pennsylvania, the Gelman Instrument Company in Ann Arbor, Michigan, and Mott-Brandon Corporation located in Pendleton, South Carolina, which represents Mott Metallurgical Corporation in Farmington, Connecticut. Mott Metallurgical makes porous, stainless-steel tube modules that are being evaluated primarily for textile applications; NASA is also funding a study of these tube modules for recycle of shower water in space stations.

ORNL has been testing a new Gelman module design fabricated of microporous films; this development, if successful, is projected to cost (based on price per unit area) an order of magnitude less than current prices of other systems. Selas has developed modules based on porous ceramic tubes, which have been tested for treatment of laundry wastes and for recovery of indigo from dyeing operations. These modules were used in the recently completed ORNL pilot-plant program in cooperation with International Paper Company for treatment of kraft pulping wastes. According to Johnson, the program carried out at the paper company's kraft plant at Moss Point, Mississippi, had mixed results: Many of the tubes were too fragile to withstand the necessary pressure and the chemical environment, but success was achieved in removing color and organic matter from bleach effluent from the plant.

Gary Westmoreland works with the cartridge, built for ORNL by Gelman Instrument Company, on which the dynamic membranes are formed for cross-flow filtration.

Filtration modules using dynamic membranes typically consist of tubes made of porous materials, such as carbon, cloth, metals, ceramics, or plastics. The membrane is formed from chemicals, such as a hydrous oxide or an organic polyelectrolyte, added to a solution circulated past the porous surface. The additive is deposited as a thin layer on the porous support. The water to be cleansed is then pumped through the system. It passes through the membranes, into the pores and out, leaving the contaminants behind. Filtration of large species occurs because the effective pore size of the membrane is small enough to prevent their passage. The mechanism by which the dynamically formed membranes filter salt is normally different; it depends on the ion-exchange properties of the membrane and on the consequent tendency to exclude ions of the same charge sign as the fixed charges on the membrane. Research results have indicated a relatively low salt rejection with feeds of high salinity. Thus, dynamic membranes are unattractive for desalination of seawater, at least in a single stage. Their potential with brackish waters has been tested at the pilot-plant level, and salt rejection is adequate in any case for many pollution-control applications.

According to Johnson, "The uses for which the technology can be considered transferred at this time involve treatment of industrial streams usually deemed as wastes. Because of the cost of equipment marketed up to now, applications have been economic only in cases where chemicals of value could be recovered."

The potential advantages of dynamic membranes over conventional membranes, such as films and hollow fibers, include higher production rates per unit area (more water is processed per unit area of the membrane) and the possibility of removal and regeneration of the membrane in the field (rather than sending it back to the factory), if fouling causes performance to become unacceptable. The wide variety of materials for construction and additives for membrane formation also open options to adapt systems for specific feeds, temperatures, and other field-operation conditions.

Technology Transfer in Four Hours

Enclosed are copies of the relevant documents pertaining to the technology transfer of the pole-zero cancellation technique. This technology transfer began with my speech at the Annual Information Day meeting of the Instrumentation and Controls Division August 13, 1965, and concluded with the publication of the paper entitled "Elimination of Undesirable Undershoot in the Operation and Testing of Nuclear Pulse Amplifiers" in December 1965. This technology transfer was so effective that within a year, it was difficult to find a nuclear pulse amplifier sales brochure that did not explicitly state that pole-zero cancellation was incorporated in the unit for optimum performance. An early ORTEC brochure boasted the incorporation of pole-zero cancellation.

Because the method of technology transfer in this particular instance was a bit unusual, I think a sequential description of the events would be of interest to you. Although I am unable to find a copy of the Information Day program for 1965, I believe that I was the first speaker. During my 15-minute talk, I gave a brief description of the electronic circuitry required for implementation of pole-zero cancellation in a nuclear pulse amplifier and a brief description of the benefits to be derived by incorporation of such circuitry.

I do not remember whether any ORTEC representative was in the audience. However, Ed Fairstein was in the audience for my speech, and left very shortly thereafter. At about 1:00 p.m., Jim Blankenship and I telephoned Ed to determine his reaction to my presentation. Ed said that he had already built and tested the circuit and confirmed our claims. He said that he intended to incorporate pole-zero cancellation as soon as possible in his Tennelec pulse amplifiers.

After concluding the telephone conversation with Ed, Jim and I discussed the conversation with C. J. Borkowski (who was then Director of the Instrumentation and Controls Division), and we decided that, because of inadequate publicity associated with the Information Day meeting and because the paper had been completed but had not yet been even submitted for publication, we had given unfair advantage to the local nuclear pulse amplifier manufacturers. We decided to compensate for this unfair advantage by sending preprints of the paper together with a specially composed cover letter to all of the nuclear pulse amplifier manufacturers that we could think of.

Dr. J. B. Horner Kuper, editor of the *Review of Scientific Instruments,* was a member of the Instrumentation and Controls Division Advisory Committee that year. He recognized the importance of early publication of the paper. Hence, he took a copy of the preprint back with him and considered the paper to be submitted for publication in the *Review of Scientific Instruments* as quickly as possible.

My goal in writing the article was to transfer a concept as well as a particular circuit. Not only is it impossible to find a nuclear pulse amplifier that does not incorporate pole-zero cancellation, but, in addition, the concept of pole-zero cancellation has been extended and used in other types of amplifiers in other ways.

—Memo from
C. H. Nowlin to Don Jared,
August 23, 1978

Surveillance and Diagnostics

When a power reactor shows signs of faltering from peak performance, the operating utility often has to call in an expert. This man, whose job is to survey the problem and render his diagnosis, is very likely to have received his expertise in this art from ORNL.

The surveillance and diagnostics group in the Instrumentation and Controls Division has seen a significant transfer to the nuclear industry of its experience with methodologies and applications over the past 10 to 15 years. This transfer results from the group's extensive interactions with universities, utilities, and vendors, and has been a natural outgrowth of ORNL's technological leadership in this country in the field of neutron noise analysis.

The commercial application of methodologies and expertise developed here has in some cases taken the form of spin-off companies established by former staff members and consultants. A company providing technical services to the utility industry, Bert Ackermann's Technology for Energy Corporation (TEC), has experienced rapid growth. Founded by Ackermann with Ted Mott and Jim Robinson, who are University of Tennessee professors and consultants to I&C Division, TEC provides consulting, measuring, and diagnostic services in acoustic-vibration noise monitoring for utility power generation facilities. TEC also offers the noise-monitoring systems to utilities to enable them to detect incipient failures in their own plants. These systems can identify potential problems by detecting cracks, leaks, and malfunctions of rotating machinery, or by monitoring loose parts and internal vibration—all through noise analysis. Much of the technology and methodology developed at ORNL has been and is continuing to be incorporated into these consulting services and monitoring systems.

Another spin-off company, Analysis and Measurement Services, Inc. (AMS), was founded by H. M. Hashemian and Tom Kerlin, a former ORNL employee and now a UT professor and consultant to the I&C Division. Tom's company has drawn from ORNL's research activities in the field of in situ testing of temperature sensors. This company offers a complete sensor-response testing program (and related measurement systems) to utilities to help them meet new regulation requirements and in situ time-response testing of sensors in safety systems.

In both of these spin-off companies, the contribution and influence of the Laboratory in their formation and success is unquestioned. The training, research experience, and exposure to multidisciplinary problems and their solutions which the company founders received at ORNL have affected the quality of the products and services these companies offer. In addition to direct spin-offs, the ongoing development of reactor surveillance and diagnostic technology at ORNL is continually being incorporated in the services and monitoring systems provided to the utility industry by reactor vendors and various noise-diagnostics consulting firms.

Another form of technology transfer is going on in the group's subcontracting work with the University of Tennessee, North Carolina State University, and the University of Florida. The surveillance and diagnostics group supports a large number of students working half-time at ORNL in partial fulfillment of their M.S. degree requirements, and an equal number who are working full-time on Ph.D. dissertations. These students, who usually begin their work at ORNL upon completion of the B.S. degree, will be at ORNL from one to four years, depending on the degree program they are pursuing. During this time, the students become well acquainted with the Laboratory's measurement systems and analysis techniques; and they often accompany staff members when measurements are required at power plants. When they graduate and begin their new jobs, often with utilities, vendors, and regulatory agencies, they transfer their broad education in noise analysis and related fields to this new work situation.

In other university contacts, Dwayne Fry and Bob Kryter have participated for several years as instructors in the week-long course offered as part of The University of Tennessee's contribution to Tennessee's Industries Week. The 15 to 30 students who take this course come from all areas of the nuclear industry, but most are employed by utilities,

Bert Ackerman left the Laboratory in 1976 to found his Technology for Energy Corporation (TEC). The business has already outgrown the building it moved into last year.

vendors, and regulatory agencies. In this way, ORNL experience in methodologies and applications is presented to highly qualified key members of the nuclear industry; this knowledge can then be used to solve problems awaiting the employees upon their return to their jobs.

Moreover, these and other researchers in noise analysis often maintain contact with the I&C researchers, requesting advice and judgment on measurements systems and analysis procedures. This mini-information center for surveillance and diagnostics helps the requestors solve their problems either by giving them information directly or by suggesting a contact who can quickly provide the information they need. This colleague-to-colleague technology transfer is once again a result of the recognition that ORNL has international experts in the field of surveillance and diagnostics.

The final area where technology is transferred by the group is through the publication of work in journals, such as *ANS Transactions, Nuclear Science and Engineering,* and *Nuclear Technology,* and participation in conferences, symposia, and working groups of professional societies. These professional activities often contribute to the formulation of standards and recommended procedures for noise surveillance and diagnostics and sometimes have wide ramifications in the testing and quality assurance programs of industries and utilities.

The most recent examples of this transfer have been the reporting of the work of ORNL consultants for the U.S. Nuclear Regulatory Commission on core–barrel motion in Pressurized Water Reactors and Boiling-Water Reactors. These activities required extensive vibration measurements at reactor sites, reviews of vendors and utilities procedures, and technical support to the NRC in their important decisions. In all of these real-world applications, the ORNL researchers have received wide exposure and acknowledgment as ambassadors to the power industry—spreading the word of how surveillance and diagnostics can increase the safety, reliability, and availability of power stations.

Measuring Time Response

The Instrumentation and Controls Division has developed a method of measuring the time response of thermocouples and resistance thermometers in situ by observing the thermometer's response to a step change in an electrical current passed through the thermometer. Called the loop-current step-response (LCSR), the method was developed by Rad Carroll and Bob Shepard, and described by them in a report to the June 1975 meeting of the American Nuclear Society. It has been used at ORNL to measure response time of thermocouples into the ORR and the HFIR, as well as measure the response time of thermocouples of various styles and sizes in a sodium loop. The technique makes possible compliance with the U.S. Nuclear Regulatory Commission's *Regulatory Guide* (Sect. 1.118), which requires the in situ measurement of the response times of thermocouples and resistance thermometers in operating reactors.

Circuit diagrams for the LCSR apparatus have been made available to the industrial community through ORNL's Office of Technology Utilization/Commercialization. A prototype industrial package combining the LCSR driving unit and signal processor is also being designed. A commercial LCSR measuring unit for platinum-resistance-thermometer response time is now offered for sale by Technology for Energy Corporation in Knoxville. TEC has used this equipment in several tests of resistance thermometers in operating water reactors under contract to various utilities.

Uranium from Fertilizer

Phosphate rock, which is a prime source of phosphate used in fertilizer, represents one of the largest known uranium resources of the United States. Estimates indicate that these extensive deposits may contain over a million tons of uranium. As the first step in the production of some fertilizers, the rock is digested in sulfuric acid to produce a phosphoric acid solution that contains about 1.5 lb (0.5 kg/2500 liters) of uranium per 1000 gal. If this uranium—plus the potential energy it represents—is to be recovered economically, it must be recovered at this point from the so-called wet-process phosphoric acid, or the uranium will be irretrievably lost by dispersal to farm lands as fertilizer. Even at this point, recovery is extremely difficult because of the strong affinity of phosphate for uranium, coupled with the low concentration of uranium present.

In the late fifties, a small amount of uranium was removed from the acid by two companies using a solvent-extraction process developed by Dow Chemical Company under an AEC contract. These plants closed down in the early sixties due to the relatively small amount of wet-process acid produced at that time (containing about 300 tons, or about 270 metric tons, of U_3O_8 per year), problems inherent in the process that made recovery difficult and expensive, and competition from low-cost uranium that became available with the discovery of high-grade sandstone deposits in the Western United States.

During the 1960s, the fertilizer industry shifted to higher-assay fertilizer to minimize sharply increased transportation costs. This trend led to increased production of wet-process phosphoric acid. Consequently, according to recent estimates, over 3000 tons of uranium—equivalent to approximately 25% of the current domestic production—will be dissolved in the acid this year and available for recovery. This is projected to increase to around 8000 tons by the year 2000, enough to fuel a 1000-MWe LWR during its operating life. Also, during the 1960s, the relatively low-cost, high-grade, western uranium deposits were being depleted; because lower-grade deposits are now being processed, costs are rising. Uranium prices today are in the \$40/lb (\$88/kg) range, compared to less than \$6/lb (\$13/kg) only ten years ago.

This turn of events renewed our interest in the acid as a long-term source of uranium, and in 1967, we started a small program to develop a more attractive method for recovery. In 1972, ORNL announced the development of a new two-cycle solvent-extraction process for separating the uranium from the acid. It offers several potential advantages over the previous process and has attracted worldwide attention. The process has been successfully tested in pilot-plant studies at several phosphate-plant sites under operating conditions; the results indicate that uranium recovery from phosphoric acid will be competitive in cost with recovery from the western ores.

The new process uses a very powerful and stable combination of reagents, which were developed earlier at ORNL for extraction of uranium after oxidation to its hexavalent state. The key to the process is in the stripping step, which utilizes a change in valence to concentrate the uranium and to allow easy recovery of a high-grade uranium oxide product in a second cycle using the same reagent.

This technique has been transferred to two commercial plants—Wyoming Minerals, a subsidiary of Westinghouse Corporation, and Freeport Minerals—both of which are due to start up this year. A third plant, International Minerals & Chemical Corporation, which will also use the ORNL technology, is in the final stages of engineering and is scheduled to start up in 1979. When all three plants are on line, production capacity will be about 900 tons of uranium per year. In addition to these facilities, a number of other companies are nearing a decision and will probably make plans to construct plants within the next few years. Representatives from over 30 companies, primarily phosphate producers and utilities, have been in close contact with ORNL for advice and consultation. (There is also a lot of interest among foreign countries, and at least one overseas plant based on ORNL technology is being built in Spain.)

Solvent extraction is a new endeavor to these people, and as a result of these contacts, ORNL is helping industry to speed up development, thereby saving valuable uranium that would be otherwise lost.

International Minerals & Chemical Corporation's Clear Springs mine at Bartow, Florida can store up to 240,000 tons of concentrated phosphate rock. Combined tonnage produced by IMC's mines during fiscal 1978 amounted to 13.2 million tons of phosphate rock, from which 750,000 lbs of U_3O_8 can be recovered by the ORNL method.

A Simple Grating Calibrator

In the broad range of experiments using radiant energy to study properties of matter, a precise knowledge of the spectral energy distribution of an unknown source is often needed.

Since the early 1960s, Ed Arakawa, Bob Birkhoff, and graduate student Dave Hammer in the Health Physics Division (now Health and Safety Research) have been involved in a detailed theoretical and experimental study of the vacuum ("far") ultraviolet radiation emitted when thin metal foils are bombarded by high-energy electrons. The emitted photon intensity is measured as a function of wavelength and electron energy, with the results being compared to theory. But for this comparison to be meaningful, it is necessary to determine the number of photons emitted per electron striking (incident on) the metal foil—and, therefore, to know, as a function of wavelength, the absolute efficiency of the grating used to disperse the emitted radiation.

At the time of ORNL's initial experiments in this area, manufacturers did not provide efficiency measurements for their gratings. Thus, ORNL developed its own simple grating calibrator. The device was quickly adopted for general use, and now absolute efficiencies for gratings are supplied on request by manufacturers such as Bausch and Lomb. In addition, W. R. Hunter at the U.S. Naval Research Laboratory in Washington, D.C., has been using a grating calibrator based on the ORNL design for his basic research on gratings.

The absolute efficiency of the grating has to be measured as a function of wavelength and for the geometry of the instrument, or setup, in which the grating is to be used. Conceptually, this measurement is simple—one measures the intensity of light of a given wavelength leaving the grating and compares it with the intensity of the radiation of the same wavelength incident on the grating.

In practice, however, all attempts to do this had proved complicated and time consuming. The ORNL design overcame many of the problems inherent in previous absolute efficiency measurements; the calibrator uses no lenses or mirrors, and the only reflecting surface in the system is the grating itself.

The device is essentially a vacuum monochromator—an instrument that produces radiation of a single wavelength—with its own built-in movable detector. The detector (or photomultiplier) is mounted on a swinging arm and placed first at the entrance slit of the calibrator. There it receives and measures monochromatic (single wavelength) radiation which is focused through the calibrator's entrance slit by another monochromator.

The detector is then swung downward from the entrance to the exit slit of the calibrator and records the radiation diffracted from the test grating, which has been rotated to the proper angle for measurement. The ratio of the photomultiplier currents measured in the two positions (exit/entrance) is the grating efficiency.—*Jeff McKenna*

awards and appointments

For the fourth consecutive year, Oak Ridge National Laboratory has earned the National Safety Council's Award of Honor for ORNL's safety performance.

Jack DeVan and **Ralph Donnelly** have been elected Fellows of the American Society for Metals.

James H. Smith has been elected Fellow of the American Society for Nondestructive Testing.

Gayle S. Painter has been elected a Fellow of the American Physical Society.

Nancy C. Cole (formerly of ORNL), **Gerald M. Slaughter,** and **Domenic A. Canonico** received the 1977 Rene D. Wasserman Award of the American Welding Society for having written the best paper published during the year in the *Welding Journal.* The winning paper is entitled "Direct Brazing of Ceramics, Graphite, and Refractory Metals."

George W. Oliphant has been named director of the Plant and Equipment Division.

Harry C. Hoy is a co-recipient of the William H. Cameron Award, named in honor of the first president of the National Safety Council. Hoy has been serving as vice chairman of the NSC's research and development section, whose outstanding safety activities have been recognized.

Bill Clark received an Award of Merit at the International Industrial Graphics Conference in Washington, D.C., for his design of the Fall 1977 *Review*.

Two Nuclear Division entries received *Industrial Research's* IR-100 Awards this year. Winners were **Charles D. Scott** for his development of a continuous-flow chromatographic system to separate materials in liquids, and **Ronald Goans** for his development of an ultrasonic sensor for detecting the depth of irreparable damage in burned tissue.

Fred Mynatt, Bob Peelle, and **Rafael Perez** have been elected Fellows of the American Nuclear Society. ORNL staff members elected officers of the ANS professional divisions are **Thomas H. Row** (Environmental Sciences, chairman), **James A. Horak** (Materials Science and Technology, chairman), **William B. Cottrell** (Nuclear Reactor Safety, chairman), **Enzo Ricci** (Isotopes and Radiation, secretary), and **Raymond E. Blanco** (Nuclear Fuel Cycle, vice chairman/chairman elect). **David E. Bartine** was a co-winner of the ANS Radiation Protection and Shielding Division's annual award for outstanding service to the Division.

Norman W. Durfee has received the "Young Engineer of the Year Award" from the Tennessee Society of Professional Engineers.

Pete Lotts has been appointed program director for nuclear fuel and waste programs.

Leon Klatts has been appointed associate editor of *Analytical Instrumentation.*

W. Wiley Johnston, Jr. has been named Fellow of the American Society for Testing and Materials, which also bestowed upon him the ASTM Award of Merit for "distinguished service to the cause of voluntary standardization in temperature measurements."

Eleven staff members of ORNL's Metals and Ceramics Division won honors at the 1978 Ceramographic Exhibit held by the American Ceramic Society in Detroit. Receiving awards were **Victor J. Tennery, Harold Keating, Wilbur H. Warwick,** and **Jay W. Nave,** first place in the Optical Micrographs Reflected Category; **Tommy J. Henson, Larry G. Shrader,** and **Terry N. Tiegs,** first place in the Electron Microprobe Category; **Charles S. Yust** and **Robert S. Crouse,** second place in the Scanning Electron Microscope (Natural Surfaces) Category; **David P. Stinton** and Henson, second place in the SEM (Fractographs) Category; and **Arvid Pasto,** Tennery, and Henson, honorable mention in the SEM (Natural Surfaces) Category.

Carl J. McHargue has been elected a Fellow of the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

Linda Svoboda, a former University of Tennessee research assistant in the Environmental Sciences Division, was awarded a prize for the "best student paper" by the Southeastern Atlantic Section of the Society for Industrial and Applied Mathematics. Her paper, "Analysis of Nonlinear Matrix Equations for Fish Population Dynamics," was based on work accomplished in 1977 under the direction of Don DeAngelis.

Rhoda Grell was inducted into the Hunter College Hall of Fame on the basis of her professional accomplishments in the field of genetics.

The Second International Symposium on Molten Salts, sponsored by the Physical Electrochemistry Division of The Electrochemical Society, has been designated the Bredig Memorial Symposium, in memory of Max Albert Bredig (1902-1977), to honor the late ORNL chemist and his many contributions to the field. The symposium is scheduled for the October 15–20 meeting of the society in Pittsburgh. Chairman of the Bredig Symposium is Jerry Braunstein.

A Coal Combustor for Cogeneration

National energy policy emphasizes the urgency for conversion to coal to replace the dwindling supplies of natural gas and petroleum. This policy, coupled with the spiraling cost of new liquid and gaseous fuels, has helped stimulate interest in the accelerated use of our extensive coal resources.

If our goal is to substitute coal for oil and natural gas, then the prime target of our efforts has to be the industrial sector. Not only is it by far the largest energy-consuming sector, but it also consumes far more natural gas than any other sector, plus a fairly large quantity of oil. Moreover, most of this energy is in the form of process heating, which is easily provided by coal. Industry, therefore, is considered the most important energy-consuming sector for conversion to coal. Any conversion to coal, however, carries with it the responsibility for conforming to the new environmental requirements. Fluidized-bed combustion of coal offers the potential to meet these environmental requirements in a cost-effective way.

The Technology

In a fluidized-bed combustor, coal is burned in a bed of limestone particles at a temperature of about 900°C. There are two unique environmental advantages inherent in this concept. First, by controlling the temperature of the combustion zone to around 900°C, the nitrogen oxide emission is reduced to about half that of a conventional pulverized-coal-fired boiler. Second, the sulfur released from the coal during combustion reacts with limestone in the bed to form calcium sulfate, which can then be removed from the bed along with the ash. Thus, noxious sulfur dioxide emissions are virtually eliminated, and the waste material is a dry, chemically inert solid which is relatively easy to dispose of in a conventional landfill—and may indeed have some attractive uses as an agricultural supplement, or as a base material for roadbeds or cement products.

We at ORNL are working with engineers from industry to design a fluidized-bed coal burner for the cogeneration of both electricity and process heat for application in industrial plants. For example, Fluidyne Engineering Corporation is conducting tests on materials of such a system for us.

This cogeneration combustor works on the principle that a power system operating on a thermodynamic cycle must reject a portion of the thermal energy received from a high-temperature source to a lower-temperature reservoir. A conventional electric plant rejects this thermal energy usually to a body of water or to the atmosphere. The efficiency of a conventional electric utility plant is only about 35%; therefore, the rejected heat from such a plant amounts to about 65% of the energy released by coal combustion. If the low temperature of the thermodynamic cycle is increased, the electrical efficiency declines; however, the heat released at a higher temperature may be suitable for industrial process heating. This is precisely what cogeneration accomplishes. A typical cogeneration cycle for this concept would provide about 20% electrical efficiency, with about 55% of the energy available as high-temperature (500°C) process heat for industrial use—a total cogeneration efficiency of 75%. The cogeneration concept provides the potential for fuel conservation and economic advantage, saving up to 35% of the cost of purchased electricity and process heat from conventional industrial boilers.

Cogeneration also offers energy conservation, in that it takes maximum advantage of the temperature availability of the energy source. Coal combustion is a high-temperature, high-availability, energy source. Many industrial applications, however, only use the energy at the temperature required for industrial process heat. By applying the concept of the coal combustor for cogeneration, electric energy can be produced from high-temperature heat available from the combustor, and process heat can be provided at the lower temperature required by the industrial process. Effectively utilizing the total energy available is as important as the conservation of fuel and is another benefit of cogeneration.

The Concept

The coal combustor for cogeneration is an air-cooled, fluidized-bed combustor with the air driving a gas turbine to produce electricity, and the exhaust air from the turbine providing process heat to industrial plants. The stack gases from the combustor preheat incoming air, which is

John Jones, Jr., presented the fluidized-bed coal-combustion concept to DOE Secretary James Schlesinger (left) and President Carter during the President's visit to ORNL in May.

passed through the fluidizing plate into the fluidized bed, where combustion takes place. The gases then pass up through the freeboard and leave the fluidized bed through a heat exchanger to give up heat to more incoming combustion air. The stack gases are then routed to a bag filter for particulate removal and are finally sent up the stack. The fluidized bed operates at atmospheric pressure with an induced draft fan pulling air through the combustor and up the stack.

Process air is a completely independent, clean-air stream. It enters the cycle and is compressed to about 600 kPa pressure. It then passes through the recuperator, which is a heat exchanger designed to transfer heat from the exhaust air of the turbine to the incoming compressed air. The extent of heat transfer in the recuperator depends upon the temperature of the process heat desired by the industrial plant. Leaving the recuperator, the process air then passes through the tubes in the fluidized bed of the combustor, where it is heated to a temperature of approximately 800°C. The air then leaves the combustor and is routed to the gas turbine, which operates over a temperature range of approximately 600 to 800°C producing electricity and driving the compressor. Exhaust from the gas turbine passes through the recuperator, giving up heat to the incoming process air. The recuperator is designed to maintain the exhaust temperature to the industrial plant at the desired level. Process heat is available to the industrial plant at temperatures ranging from 250 to 500°C, depending on the process-energy requirements. Thus, the total cogeneration efficiency is about 75%—that is, 75% of the energy input to the combustor in the form of coal is effectively used, either in electricity or in process heat.

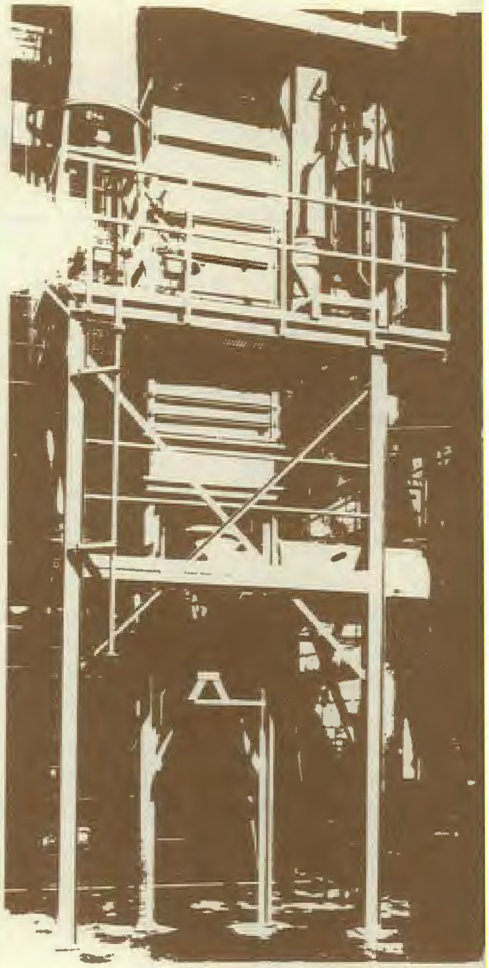
Test Unit Planned

Commercial sizes for the concept are envisioned to be in the order of 5 to 50 MWe. A 200-kWe technology test unit is planned for construction to demonstrate the reliability and practicability of the concept. Initial operation of the combustor will be on compressed air in an open-cycle mode for a 6000-hr test with specific emphasis on the corrosion/erosion performance of the heat-transfer tubes. Following this test period, the turbine will be installed for operation as an open-cycle gas turbine unit; finally, the third phase of the test program will consist of operation in a closed-cycle mode with the gas turbine. The ORNL design and development team is led by Bob Holcomb and includes Ralph Guymon, Mack Lackey, Chuck Claffey, Bob Delagrange, Fred Lynch, and John Tudor.

Market Study for Commercialization

A preliminary market assessment for the coal combustor for cogeneration has recently been completed by Ron Graves and Bob Tallackson. They found that process heat accounts for about 61% of the total energy used in industry. An examination of the six major sectors of industrial process-heat use reveals that four industrial sectors—petroleum, chemicals, paper and pulp, and food processing—are well suited for this technology. Further, they found that if the coal combustor for cogeneration were applied to those industrial processes that now use oil and natural gas, the savings would amount to 1.5 million barrels of oil per day and almost 18 billion ft^3/day of natural gas. More detailed analysis of eight specific industrial applications revealed that the most attractive, energy-efficient application is in the production of newsprint from dry pulp, where a total energy efficiency of 78.6% is achieved. When supplying process steam at conditions suitable for a chemical or petroleum-refining application, the fluidized-bed coal combustor for cogeneration will produce 26% more electricity than a coal-fired boiler in the cogeneration mode.

The market survey is the first phase of a larger commercialization plan for the concept, which will involve strong industrial participation throughout the program. In addition to the market study, private industry is being engaged in the design of the test unit itself. A request for proposal will be initiated to solicit detailed designs for the test combustor and for a commercial-size unit from equipment manufacturers that could market the technology. One of these equipment manufacturers will be selected to build the test facility.



A third aspect of commercialization plans is to establish an advisory group made up of industrial energy users and equipment manufacturers. The advisory group will meet periodically with DOE and ORNL personnel, its function being to review the progress and plans to ensure that the technology being developed fits the needs of the potential users.

The fourth aspect of commercialization is to initiate three or four site-specific application studies in cooperation with industry. The industrial plants will be selected from the six major categories of process-energy users. A greater part of the studies will be performed by industrial-engineering or consulting firms.

These application studies will provide feedback to guide the concept development; they will identify potential applications for the technology; and, most important, they will acquaint industry with the concept.

The fifth aspect of the plan will be to conduct annual program information meetings, open to all interested organizations and individuals. A special attempt will be made to involve industrial energy users, equipment manufacturers, and architect-engineering firms serving the industrial sector. In addition to these specific information meetings, a continuing effort will be made to inform industry of progress of the test program through the ORNL Office of Technology Utilization.

The last phase of the commercialization plans calls for participation in one or more industrial demonstration projects, to be jointly supported by government and industry. The ORNL role in these projects will be to provide technical support to the Department of Energy in carrying out the government's role in the demonstration-plant projects.

Extensive contacts in government and industry have already been established. In government, the Presidential entourage was briefed last May while at ORNL. President Carter, DOE Secretary James Schlesinger, Presidential Science Advisor Frank Press, John Deutch of the Department of Energy, Senators Howard Baker and James Sasser, Congressman John Duncan, Congresswoman Marilyn Lloyd, and several others heard John Jones' presentation. On a separate occasion, Dale Myers, Undersecretary of Energy, Bob Thorne, head of Energy Technology, and George McIsaac, head of Resource Applications, were briefed on the technology.

In industry, extensive communication has been established with such equipment manufacturers as Babcock & Wilcox, Westinghouse Electric, Curtiss-Wright, Dorr Oliver, Fluidyne Engineering, Garrett Corporation, and General Electric, as well as potential industrial users.

Jones' group recently briefed possible user representatives from Union Carbide, Celanese, Monsanto, Sears Roebuck, 3-M Company, and Goodyear Tire & Rubber. The concept has also been discussed with representatives from Dow Chemical, the California Energy Commission, Cities Service Oil, Penn Oil, TVA, and Southern California Edison.

Power Systems Engineering Company, a Texas-based firm involved in building and operating energy systems at industrial plants, has indicated a strong interest in working with ORNL to identify specific industrial customers for whom this technology would be applicable.

An invited paper is to be presented on the "Coal Combustor for Cogeneration" at the *Coal Technology '78 Conference,* an industrial conference to be held in Houston, Texas, this October.

The technology is on the threshold of commercial application in an area of urgent national need and interest; consequently, efforts are going forth to maintain and expand all contacts throughout the progress of the program.

Residential Energy Use

The ORNL Energy Division is involved in the transfer of computer software to government and industry. Eric Hirst, research engineer in the energy conservation section, with several others, has developed a residential energy-use model which is used for evaluating the effects of energy conservation policies, programs, and technologies on energy use and costs. The model simulates national energy use on an annual basis for four fuels (electricity, gas, oil, other), eight end uses (space heating, water heating, refrigeration, food freezing, cooking, air conditioning, lighting, other), and three housing types (single-family units, multifamily units, mobile homes). The model was tested by comparing model results with actual energy-use data for the period from 1960 to 1976. Model predictions are accurate for residential energy use in the aggregate, by fuel, and by end use, and are also good for equipment-ownership market shares.

The model has been used extensively for evaluating government-sponsored conservation programs, and has also been used by various private companies, such as the Economic and Market Research Division of the Carrier Corporation. Carrier maintains active correspondence with ORNL concerning use of the model.

The technology transfer process is uncomplicated; it consists of ORNL's sending to the user either a box of punched cards plus a user's guide, or a magnetic tape plus a user's guide. When the company receives a tape, the tape is copied and returned. So far, there have been no charges for this service.

Development of the residential energy-use model has been sponsored by the Energy Research and Development Administration, the Federal Energy Administration, and now the Department of Energy. Initial users of the model were government agencies, chiefly the sponsors. However, the number and variety of users are growing and include utilities such as the Tennessee Valley Authority, Southern California Edison, and Northern States Power Company; and private companies such as Carrier Corporation, Resource Planning Associates, Energy and Environmental Analysis Inc., TRW Inc., and Hittman Associates. Hirst's residential- and commercial-energy-systems analysis group has many ongoing studies that use computer programs to evaluate use of energy in buildings. Heat pumps, refrigerators, and water heaters are among the equipment they are studying. The technology developed by this group is not slow to reach beyond ORNL. It is bound to have some direct influence on our private lives.—*Betty Galyan Shields*

NDT in Industry

The traditional route by which national laboratory technology reaches the private sector has always been through the open literature. A technical development achieved with public funding is available to the world as soon as it has been described in a technical publication. So it has been with the ORNL developments in nondestructive testing (NDT). For many years, the extent to which this NDT has been picked up and used by industry has only been discovered inadvertently, and the identity of user companies has been learned only by accident.

Recently, however, the developments of Bob McClung's NDT laboratory have appeared in the newly instigated Technology Utilization bulletins, and the resulting inquiries have permitted identification of a number of industries and their interests.

For example, one of the earliest significant developments of the NDT group was the immersed ultrasonic inspection of tubing. The technique involves transmitting high-frequency pulses of ultrasonic waves (too high-pitched for the human ear) through a water coupling (or column) into the wall of a tube. Cracks or other discontinuities reflect portions of ultrasound back to a search unit, and signals are processed electronically to yield information on the severity and location of defects. Such techniques have become standard in the industry since the early 1960s when they were first adopted by such firms as Superior Tubing Company. Virtually every tubing fabricator and tubing-inspection laboratory in the world use the techniques that were developed and reported by ORNL.

Pulse-echo ultrasonic techniques and instrumentation for direct digital display of thickness developed for in-service inspection of the Homogeneous Reactor Test (HRT) core vessel were the forerunners of current ultrasonic thickness-measuring equipment used widely in industry. K. V. Cook and McClung developed the technique to measure the HRT vessel wall thickness. This technique allows determination of thickness based on knowledge of the velocity of high-frequency pulses of sound through a specific material and the measurement of the time elapsed between echoes from the surfaces of the specimen.

Eddy Current Testing

The development of an eddy-current instrument to distinguish between Inconel, stainless steel, and other alloys in order to prevent inadvertent mixing was not only beneficial at ORNL for the Aircraft Nuclear Propulsion Program in the 1950s, but also was recognized for its value to industry in general. The instrument was based on the principle that an alternating current when passed through a coil of wire will induce the flow of electrical current (eddy current) in a nearby conductor. The flow of current in the specimen will reveal many of its properties, such as thickness, electrical conductivity, and, therefore, alloy identification or verification. The instrument was developed at ORNL by J. W. Allen, R. A. Nance, and Floyd Glass. A commercial instrument manufacturer obtained the drawings through the AEC and marketed the instrument for alloy sorting for several years.

Eddy-current probes, which were developed by McClung and C. V. Dodd for measuring the coolant-channel spacing in nuclear-reactor fuel elements, were adopted by others in the nuclear industry to measure fuel elements before and after service. At least one commercial supplier of equipment fabricated the probes. Texas Instruments' Metals and Controls Division in Attleboro, Massachusetts, uses the technique to check for uniform spacing in coolant channels of High Flux Isotope Reactor fuel cores.

The development of advanced theory and computer programs for electromagnetic induction in general, and eddy currents in particular, has been a significant advance in eddy-current nondestructive testing that has been recognized and used by many organizations in the United States and abroad in aerospace, nuclear, instrumentation, and other fields to solve eddy-current inspection problems. Friedrich Foerster, an eminent German who is considered by many to be the father of modern eddy-current inspection and the largest manufacturer of eddy-current instruments, has cited ORNL publications on this subject as the best sources of technical information.

Significant advances have been made in ORNL-developed phase-sensitive eddy-current instrumentation (invented by Dodd in 1962) that overcame some of the basic limitations of commercial eddy-current techniques. The newer equipment is highly sensitive, stable, and reliable. Used by airlines, aerospace, and nuclear industries, the ORNL-developed equipment has been manufactured and marketed by three commercial firms in the past. General Electric is using the equipment to examine high-temperature coatings; Pratt and Whitney is using it to check jet-engine components, and BOAC, for maintenance procedures. An interesting but little known sidelight was its application in NASA's Apollo program in the 1960s. According to McClung: "There was concern about a mix-up of materials on turbine blades in Saturn 1B boosters after assembly and installation in the rocket motors. Improper materials would have caused a spectacular failure within approximately 100 sec after launch. After unsuccessful attempts by private industry to resolve the problem, we used the phase-sensitive instrument and specially designed coils, and examined approximately 70 rocket motors at various locations—including two on the launch pad—and provided assurance for the motors to be used. It

C. V. Dodd (left) and Ed Fairstein, chief technical designer for Tennelec, discuss components over the dual-frequency, phase-sensitive, eddy-current instrument developed at ORNL by Dodd and being manufactured by Tennelec, Inc., in Oak Ridge. Fairstein himself is an example of technology transfer to industry, having left ORNL in 1961 to found the corporation. The instrument is capable of monitoring four properties of metal plating simultaneously, a capability of considerable value to the aircraft industry, among others.

was estimated that the direct cost savings was millions of dollars which would have been required to disassemble, check, and reassemble the motors, not considering the large schedule delays."

The equipment and techniques that have been developed by B. E. Foster and J. W. Evans for quantitative measurement of x-ray and gamma attenuation in specimens and components have been widely adopted in the nuclear industry for measuring homogeneity in nuclear-reactor fuel plates and rods and for measuring density in graphite. Various industries have also used the equipment and techniques for measuring porosity in core drillings and in scanning electrical-resistant heaters.

Radiography

Radiographic techniques and standards for determining homogeneity in fuel plates for Core B of the Enrico Fermi Reactor have been used as guidelines by fuel-plate manufacturers for other fuel elements. Texas Instruments uses ORNL-developed radiation techniques and equipment to check for uniformity of fuel loading in fuel plates made for the HFIR. In these techniques, x rays transmitted through fuel plates are attenuated as a function of thickness, composition, and density of the material. X rays are weakened more by passage through uranium than through aluminum in HFIR's uranium-aluminum fuel plates. By using a detector to pick up the emerging x rays and converting them to a proportional electrical signal for readout on an attached instrument, one can map out variation in fuel content. Babcock and Wilcox and the General Electric Company have used variation of the technique in the manufacture of reactor fuel elements, and Avco has employed it in studies of aircraft materials.

In 1962, the American Society for Nondestructive Testing bestowed the Coolidge Award on McClung for the development of techniques for low-voltage radiography. Since then, these techniques have been widely used by the nuclear industry, the Air Force, the aerospace industry, beryllium suppliers, and others. The technique was developed to look for flaws and changes in density or thickness in thin lightweight materials, such as aluminum, graphite, and beryllium. Low-energy x rays are directed toward the specimen, which easily absorbs the radiation. The extent to which it is absorbed varies according to thickness, density, and chemical composition; this degree of absorption is recorded on film or high-resolution photographic plates. In the related development of contact microradiography, the radiographs are magnified so that microscopic detail can be seen. This technique, developed for close inspection of coated fuel particles for gas-cooled reactors, has been used by General Atomic and others for this application as well as for other uses, such as composite fibers for aerospace structures and microscopic components for computers. Eastman Kodak reprinted and distributed 5000 copies of McClung's paper, "Studies in Contact Microradiography."

Development studies using radiography, ultrasonics, eddy currents, and penetrants for NDT of beryllium originated at ORNL and provided significant advances which were adopted by the air-frame industry and others interested in applications of beryllium. Although the work was accomplished about 18 years ago, a recent survey by Battelle on NDT techniques for beryllium indicated that the ORNL developments were still among the best available.

Other ORNL-developed NDT techniques that have been adopted by the nuclear, aerospace, and other industries include:

- Ultrasonic techniques developed for the detection of lack of bonding between the cladding and fuel in nuclear fuel plates.
- Unique ultrasonic techniques that were developed for the examination of tapered tubing (having a varying diameter).
- Ultrasonic frequency analysis.
- Improved techniques for making reference discontinuities in sheet, plate, and tubing, using electrodischarge machining.

Most recently, industry has shown interest in using ORNL-developed instrumentation for enhancing radiographs and in applying radiographic, ultrasonic, and eddy-current techniques being developed for the Breeder Reactor Steam Generator Program.

Thus, the technology of nondestructive testing has been and is being widely used in industry. And there is ample evidence, based on requests for ORNL publications, that much of the NDT technology transferred to industry had its starting point at the Laboratory.

Alternate Fuels for Industry

Increasing curtailments of natural gas for process-heat applications in U.S. industries have required managers in such industries as steel, ceramics, petroleum, and aluminum to find alternatives. In early 1976, ERDA, now DOE, initiated a program in ORNL's Metals and Ceramics Division to determine industrial fuel planning for the immediate term and to identify the state of technology for refractories and refractory insulations in relation to use of candidate alternate fuels. A survey of U.S. industrial-fuel strategies for the period 1977–85, conducted by Vic Tennery and George Wei, showed that fuel oils were favored as alternate fuels, and that a strong shift to oil from gas was under way even before the winter of 1976/77.

The heavier, less clean, so-called residual oils proved to be of considerable interest to industry due to their favorable cost advantage over the cleaner-burning distillates in most areas of the United States. Supporting this advantage was the industrial concern that distillate oils may be allocated for the residential and commercial sectors in the future if supply could not meet demand. Several companies were identified that had used residual fuel oils in high-temperature furnaces, and many reported the very adverse effects of the impurities on their furnace equipment. In some cases, refractory systems which previously had service lives of several years survived for only a few months. Refractory field samples solicited from these industries were analyzed by ORNL investigators Wei and Tennery, and results have been reported to U.S. industry through 11 ORNL presentations and 5 ORNL reports as of June 1978.

Additionally, a Refractory Test Facility (RTF) for conducting controlled oil-combustion testing with refractories and insulations became operational at ORNL in April 1977. (Using this furnace, Arvid Pasto and Irv Federer conducted two tests of about 500-hr duration on several generic refractories at hot-face temperatures of 1300 to 1400°C.) Already the results of the first test have been reported and distributed to respondents in industry.

The results indicate that the residual oils now available on the market contain impurities that are detrimental to specific refractory materials and insulations used in furnace linings. For example, furnace linings containing magnesium oxide swell from reactions with oil that is high in impurities such as sodium and sulfur, and alumina-silicate brick is degraded by reactions with vanadium in residual oil. Such results suggest that if there is a thorough understanding of which impurities in oil attack specific refractory materials, then industry will have a basis for selecting furnace linings if the impurity content of the oil being used is known. The ORNL findings also imply that there is a need for better refractory materials, although it might be more economical to develop an extracting technology to remove harmful impurities from the oils on the market.

Many industries have used the results published in ORNL reports to guide them in selecting high aluminum oxide–based insulations and oils. If a company wants to use a fibrous insulation to cut back energy consumption, it is advisable based on ORNL data to steer away from use of oil high in zinc. Such industries include Ford Motor Company, General Refractories Company, Carborundum Company, General Motors, Du Pont, Babcock & Wilcox, Kaiser Refractories, PPG Industries, Republic Steel Corporation, and the Norton Company. Plibrico Company has used ORNL results to guide its materials development program which aims at producing more resistant refractories. More than a dozen industries have sent decrepitated samples from process-heating equipment to be analyzed by ORNL. Tennery and Wei have worked closely with the Refractories Institute in Pittsburgh, the research arm and trade organization of the refractory industry.

The relationship between the Laboratory and industry in this area of research has been strong, partly because the lines of communication have been excellent. A national workshop on alternate fuels and known effects of fuel impurities on furnace linings was organized by ORNL and held in Washington, D.C., on September 21, 1976. Recent results of the ORNL studies were exhibited at the Fifth Energy Technology Conference held in Washington, D.C., on February 27–March 1, 1978. More than 150 industrial representatives are on the distribution list for ORNL technical reports on this subject, and a series of three articles on the ORNL findings appeared in the November 1977, December 1977, and January 1978 issues of *Industrial Heating,* a trade magazine with a readership of 20,000.

Enriched Stable Isotopes

Following the end of World War II, which saw the electromagnetic separators (calutrons) at the Y-12 Plant used for the production of enriched uranium-235, the AEC observed that these same devices could be used to provide enriched stable isotopes of almost any element. It was recognized that by irradiating isotopically enhanced nonradioactive material in either an accelerator or a reactor, both the production rate and purity of the final radionuclide could be dramatically improved. This arises from the fact that in every gram of isotopically enriched material, in comparison with a gram of normal material, a greater percentage of atoms are transmuted to the desired radionuclide (hence, the increased production rate), and fewer atoms of other isotopes of the element are transmuted into undesirable radionuclides (hence, the increased purity).

The program to produce isotopically enriched samples was initially designed to serve the AEC research community by providing targets for the study of basic nuclear properties and to measure nuclear cross sections for fission and fusion reactor programs. However, it soon became apparent that these materials could have worldwide applications in the commercial sector. Thus, the program was modified to include the distribution of isotopically enriched samples to everyone.

The largest single commercial user of enriched isotopes is the nuclear medical community. Approximately 25 isotopes are routinely used in the preparation of specific radiopharmaceuticals that function in diagnostic and therapeutic medical procedures. The chemical properties of many elements make them site specific within the human body. For example, calcium is one of the basic elements of bone; iodine is accumulated in the thyroid; and thallium is concentrated in blood. The choice of the radiopharmaceutical used is determined by its intended use.

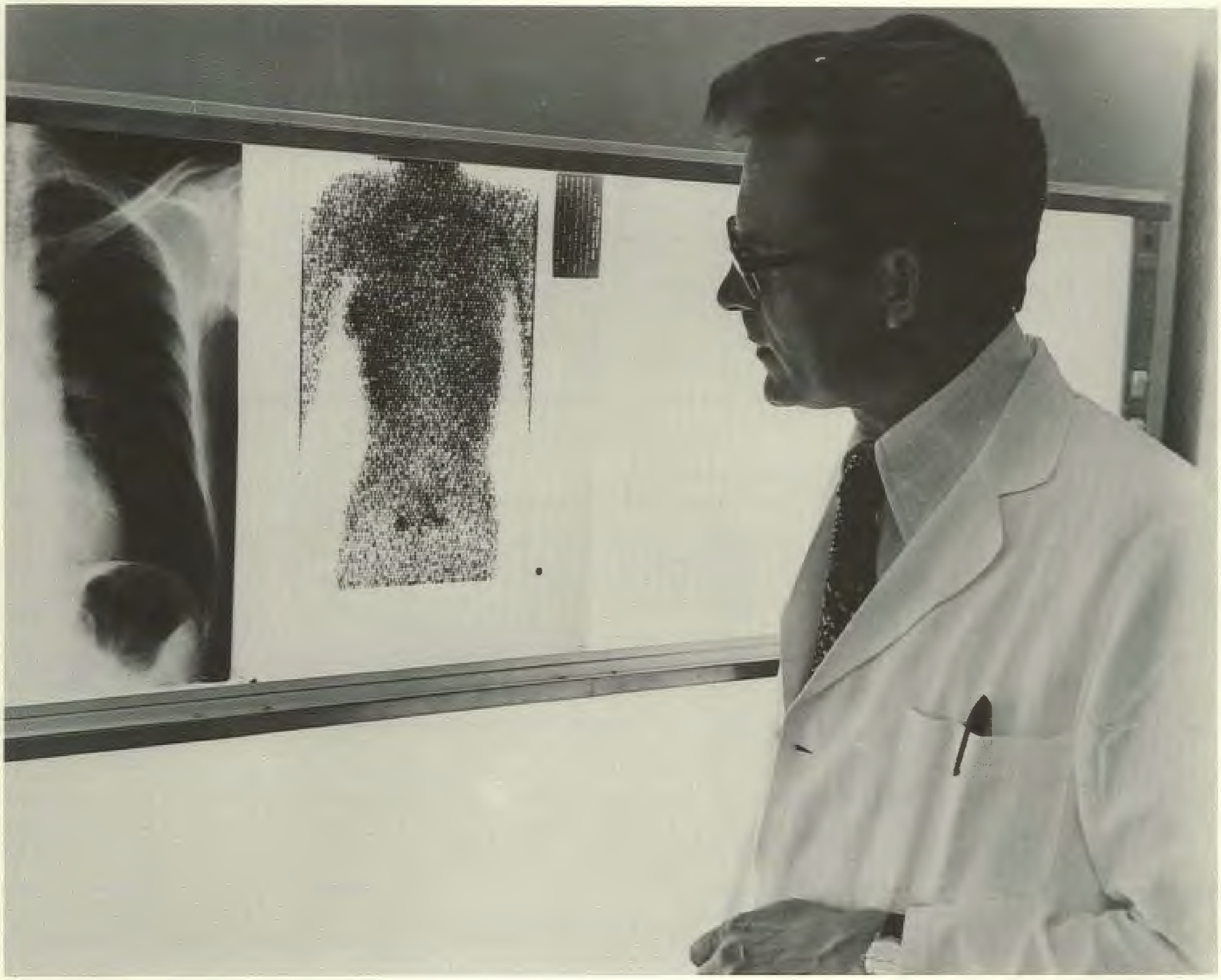
One of the most rapidly growing diagnostic procedures involves the use of the radioisotope thallium-201. This isotope is produced by the cyclotron bombardment of enriched ^{203}Tl, a stable isotope, and is used in heart scans to assess damage following a coronary attack. More importantly, it can also identify potential heart attack victims.

Another radiopharmaceutical, iodine-123, illustrates a reason for using isotopically enriched starting material. This tracer is used in thyroid scans and uptake studies. This particular radioiodine has a short half-life, an advantage in diagnostic work because it lessens the radiation body burden. The other radioiodines, ^{124}I and ^{131}I in particular, have longer half-lives and decay by emitting higher-energy gamma rays, making them undesirable contaminants. By enriching natural tellurium to the state in which it is almost completely isotopically pure ^{122}Te, and by using this material as a base for the production of the desired ^{123}I, most of the unwanted radiations are eliminated.

In addition to using isotopically enriched material as a starting point from which radioisotopes are produced, it can also be used directly in some medical procedures. Enriched, stable calcium-48 can be used to determine the rate at which children replace calcium in bone. The technique makes use of the difference between the isotopic assay of enriched ^{48}Ca (about 96%) and the ^{48}Ca in normal calcium (about 0.2%). By determining the content of that particular isotope in the calcium eliminated from the body after the ingestion of an isotopically enriched preparation, the physician is able to make a diagnostic evaluation of the bone retention without resorting to a radiological procedure.

There are many uses outside the medical field where ORNL-produced enriched isotopes are used by private industry. For example, either enriched cadmium-112 or cadmium-114—for this application they are interchangeable—is used in the helium-cadmium laser. For this particular laser, it is desirable to have the narrowest possible frequency spectrum of the emitted light. To accomplish this, the cadmium used should have as little of the odd-mass cadmium isotopes as possible, since it is these isotopes that are responsible for widening of the frequency spectrum.

One additional application of enriched stable isotopes by industry touches our lives almost every day. The properties of rubidium-85 are such that the frequency



transition between two atomic states makes an extremely accurate time standard. An atomic clock, manufactured with enriched ^{85}Rb from ORNL, is used in TV broadcasting stations to synchronize the various signals which make up each color video frame.

These are just a few of the applications of enriched stable isotopes in the commercial sector. From past experience, it seems obvious that new and more varied uses will develop, and these applications will continue to emphasize the role of the separations program.

Radioisotopes to Industry

The manufacture of radioisotopes is a relatively new business that has grown from the first reactor production of carbon-14 at ORNL in 1946 to a broadly based industrial enterprise comprising reactor and accelerator production, synthesis of tagged compounds, preparation of radiopharmaceuticals, and manufacture of radiation sources. Approximately 100 private firms, most of which were formed over the past 15 years, are currently engaged in

Dr. Karl F. Hubner, director of the Outpatient Nuclear Medicine Laboratory at Oak Ridge Associated Universities Medical and Health Sciences Division, examines a carbon-11 diagnostic scan.

the production, processing, and distribution of radioisotopes and the sale of equipment and products using them. The marketing of radioisotopes is a $50 million/year business, and sales of equipment and products involving their use are on the order of several hundred million dollars annually.

The impact of radioisotope applications upon industry can be illustrated by a quotation from a speech by Dr. Glenn T. Seaborg, Chairman, U.S. Atomic Energy Commission, on July 31, 1969:

The history of industrial application of radioisotopes is, in microcosm, the story of how government-supported science can be applied to increase the productivity of industry and thus expand our nation's economy. Fifty percent of the 500 largest manufacturing concerns in the United States use radioisotopes. About 4500 other firms also are licensed to use radioisotopes. Innumerable other companies use exempt quantities of radioisotopes under AEC general licenses. These thousands of firms benefiting from radioisotopes come from virtually every type of industry, including the metals, electrical and transportation industries, chemicals and plastics, pharmaceuticals, petroleum refining, paper, rubber, stone, clay and glass products, food, tobacco, textiles, crude petroleum and natural gas, mining, and the utilities.

The economic benefits resulting from the use of radioisotopes in the United States are conservatively estimated as greater than $100 million annually. Some of the ways that these savings are obtained include decreased waste of material and improved product quality using radioisotope gages and radiographic units, increased life of mechanical components resulting from wear studies using tracers, safer materials because of nondestructive testing (NDT) with radiography, and optimization of chemical processes resulting from tracer studies.

The social benefits accruing from the use of radioisotopes are not readily quantified, but are nonetheless highly important. In medical applications, radioisotopes save lives by improving diagnostic and therapy systems; they decrease suffering, and they provide improved health care.

In addition to these indirect benefits, industry has also benefited directly from the transfer of radioisotope-production technology developed at ORNL. This transfer of technology and profitable products have proceeded in an orderly manner over the past 25 years in accordance with the provisions of the original Atomic Energy Act. As private industry develops the capability of producing radioisotopes that are regarded as potentially profitable, the government is petitioned to withdraw from the distribution of such products. Of some 100 radioisotope products and services once provided by ORNL, 67 have been withdrawn from routine distribution by ORNL and are now provided by such industries as New England Nuclear Corporation, General Electric, and Union Carbide Corporation. Most notable among these products are ^{14}C, which is incorporated into a large number of organic compounds for research applications; ^{60}Co, widely used for radiography and teletherapy; ^{192}Ir, the premier radiographic radioisotope; ^{131}I, an important medical isotope; ^{32}P, used as a tracer in agricultural research; and fission product ^{99}Mo, parent of ^{99m}Tc which has the greatest application of all radioisotopes used for medical diagnosis. In all these cases, ORNL has transferred to industry a developed market, a customer list, and detailed production and analytical procedures for the products.

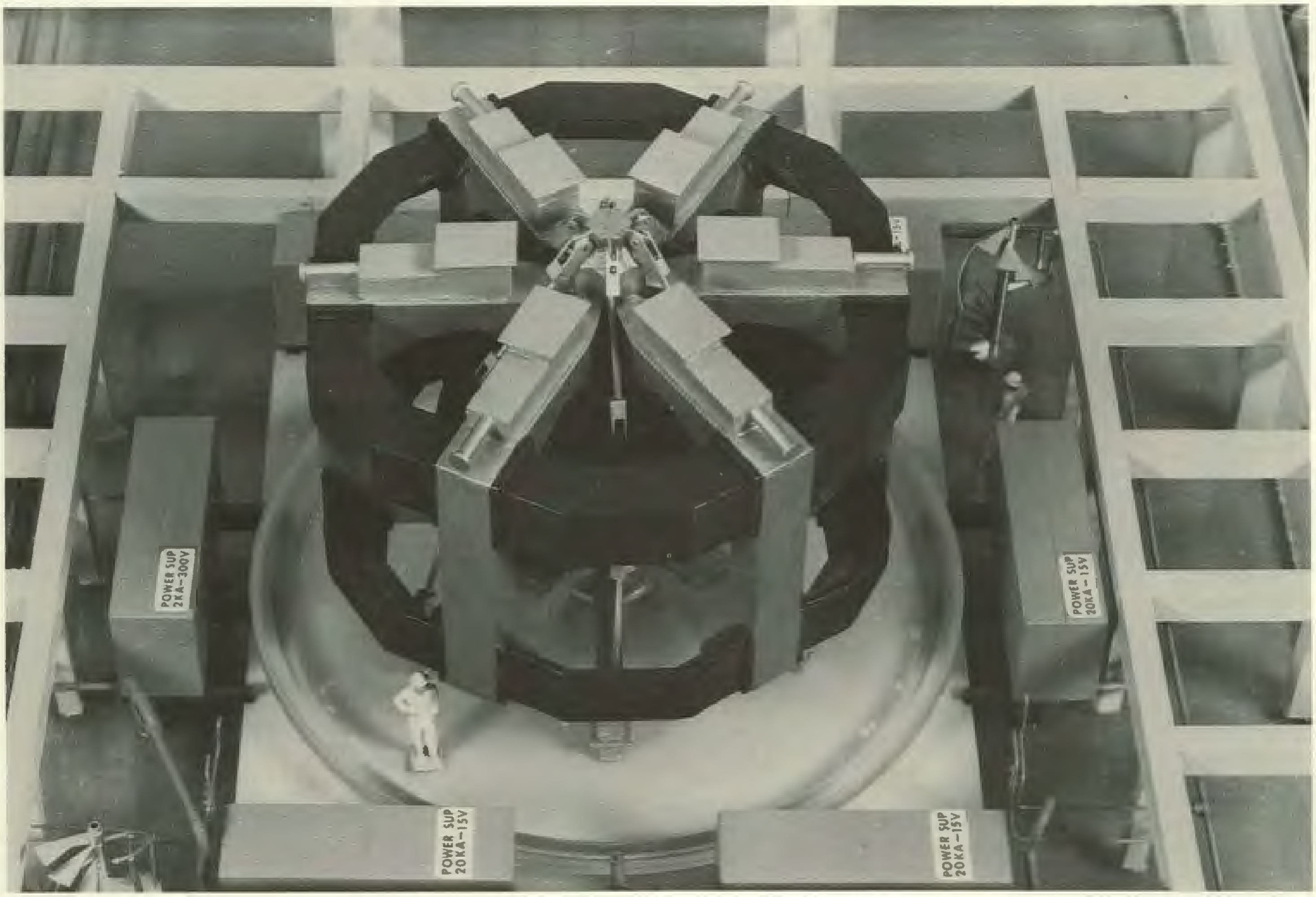
ORNL continues to serve private industry by providing radioisotope products and services and by developing new products and their markets. In many cases, ORNL serves as the primary producer and private industry as the final product manufacturer, such as in the case for cyclotron targets irradiated on the ORNL 86-in. cyclotron but processed by industry.

Fission product ^{133}Xe, used in medicine for lung studies and in industry as a gas tracer, is supplied by both ORNL and industry using technology developed at ORNL. Gallium-67, a radioisotope developed by ORNL and tested cooperatively with medical institutions as a tumor-imaging agent, is being produced by New England Nuclear Corporation. Cesium-137 sources (containing more than 1400 Ci) are fabricated for use in radiographic and teletherapy units. The ORNL technology for fabricating isotopic power sources containing ^{90}Sr is used in units producing power in several remote locations.

Gadolinium-153 serves an important function in the detection and diagnosis of bone disorders.

ORNL also serves as the distribution point for radioisotopes produced at other DOE sites. Americium-241 is very important to our energy supply because it is used by private industry to manufacture neutron sources used to define the composition of strata in oil wells and thus enhance their yields. It also is used as the ionization source in smoke detectors. Tritium is enjoying a rapid growth in demand due to its incorporation by industry into small luminous kernels which are used as backlights in liquid crystal displays of wristwatches and calculators. Krypton-85, both normal fission-product concentration and enriched, is supplied by ORNL and used by industry in the production of activated phosphor lights, in NDT testing systems, and in instruments.

The Radioisotope Production Program at ORNL, while operating to the benefit of the American public and private industry, has also operated at no net cost to the taxpayers because the cost of production is recovered by proceeds from sales of radioisotope products and services.



The Large Coil Program

One of the largest examples of industrial interaction at the Laboratory is now taking place in the Fusion Energy Division, which is participating in the U.S. Large Coil Program (LCP). Three American manufacturers have entered into contracts totalling over $15 million to design and construct

This is a model of ORNL's Large Coil Test Facility, which will test internationally designed and constructed superconducting magnets. Three of the coils are being fabricated by General Electric, General Dynamics, and Westinghouse in this country, with three more to be supplied by Euratom, Japan, and Switzerland.

superconducting-toroidal-field coils for testing to determine the best design for use in tokamak fusion reactors. At the same time, ORNL is designing and building the Large Coil Test Facility (LCTF) in the Y-12 Plant in order to be ready for the coils when they are completed, two to three years from now.

The LCTF has provided a focus for worldwide interest in the development of superconducting toroidal field coils. Under the terms of an agreement of international cooperation effected through the International Energy Agency, Euratom, Japan, and Switzerland will each build one coil and deliver it to Oak Ridge for testing along with the U.S. coils.

The U.S. LCP was established by the Division of Magnetic Fusion Energy (now the Office of Fusion Energy, DOE) in 1976. The objective is to demonstrate that superconducting-magnet technology can be extended to meet fusion program needs. The basic approach of the program is to utilize the capabilities of industry and to disseminate the results of government-sponsored magnet R&D by contracting for the conceptual design, verification tests, detailed design, and fabrication of different test coils.

In February 1977, five industrial teams submitted proposals for this work. Subcontracts on a cost-plus-fixed-fee basis have now been let to General Dynamics' Convair Division, supported by Intermagnetics General and Magnetic Engineering Associates; General Electric with Intermagnetics General and CBI Nuclear; and Westinghouse with Airco. Because it is the purpose of the LCP to pursue several coil concepts, the specifications that are part of the subcontracts describe only the required performance, the spatial limits, and the interface dimensions. The specifications place the responsibility on each seller to define credible events within its coil, and to assure its stability. Superconductor materials may be either niobium-titanium (NbTi) or niobium-tin (Nb_3Sn), and the internal design of the coil is left to the contractor. The LCP staff at ORNL provides program management, technical review, and guidance to the subcontractors.

Tokamak power reactors eventually will require magnetic fields of large volume, field strength, and duration in order to confine a plasma of heavy hydrogen isotopes so that nuclear fusion can occur, resulting in the release of large amounts of energy to generate electricity. The only economically attractive way to produce these magnetic fields is to use superconducting magnets, which consume far less electricity than do conventional copper electromagnets. Certain conductors, such as niobium-titanium alloys, when chilled by liquid helium to temperatures approaching absolute zero, completely lose their electrical resistance so that current can flow without resistive losses. With no resistance to overcome, superconducting magnet systems consume 2 to 5% of the electricity requirements of a conventional magnet system, the only power required being that used by the refrigeration system to keep the superconductor cold (4.2°C above absolute zero).

Each of the six coils that will be delivered to Oak Ridge from 1980–82 will be D-shaped, about 5 m tall and will weigh about 41 tonnes (45 tons). Roughly half of the weight is in the winding (conductor and electrical insulation, with passages for helium coolant); the balance, in the metal housing that surrounds and supports the winding. The superconductor itself (niobium-titanium in five coils, niobium-tin in one) is in the form of thousands of hairlike filaments imbedded in the copper wires that make up the conductor cables. Each coil will carry a current between 10,000 and 16,000 amperes. All six coils will be brought together in an array that will look from above like a six-pointed star, so that their effects will combine to produce a magnetic field of 8,000 tesla (about 150,000 times the natural field of the earth). The test array will be located in a tank 11 m in diameter, which will act as a huge vacuum bottle to permit the coils to be chilled to their operating temperature.

When the coils are in place and operating in the test stand at Y-12, researchers will be able for the first time to observe large coils with complicated field shape and extremely strong magnetic forces operating at a high current density in the presence of pulsed fields. ORNL researchers will be testing how well the coils retain their superconducting properties while being subjected to experimental mechanical and thermal stresses typical of those expected in large tokamak reactors. In some tests, half-turns of the coils will be warmed briefly by electrical heaters, thus causing some electrical resistance to return until the heat can be dissipated by the coils' internal cooling system. This test will simulate heating that would occur as a result of neutron radiation from a fusing tokamak plasma or from mechanical friction induced by slipping of layers of the winding at the point where the coil is flexed by the tremendous magnetic forces. Engineers will determine the maximum magnetic field achievable for each coil and the limiting factors preventing even higher performance. In short, tests will show how reliable the coils are for tokamak operation and what improvements in the engineering design might be made to increase reliability and performance.

In addition to the companies identified above as part of the Large Coil Program, the Fusion Energy Division has also let contracts totalling about $1 million to five other firms:

- *Bechtel National, Inc.,* for evaluation of a committed fusion site;
- *Exxon Nuclear Company,* for consultant services in the area of fusion-power R&D in support of the Division's plasma-engineering and Elmo Bumpy Torus programs;
- *Grumman Aerospace,* for design and project-engineering services on ISX-B and the Large Coil Program and for engineering assistance to The Next Step project;
- *Robert B. Jacobs Associates, Inc.,* for consultant services to the Large Coil Program;
- *System Development Corporation,* for engineering support services to the Large Coil Program, ISX-B, and TNS.

HASTELLOY® alloy N

One of the best examples of technology transfer to industry from ORNL is HASTELLOY® alloy N or Nickelvac-N, an alloy developed by the Laboratory under the name INOR-8. HASTELLOY® alloy N is now being manufactured by Haynes Stellite, whose parent company is Cabot Corporation, and Nickelvac-N is manufactured by Teledyne ALLVAC. The metal's main use is for components of jet aircraft engines.

INOR-8 was developed at ORNL from 1956–58 to withstand the extremely high operating temperatures and corrosive fluids that were characteristic of the Molten Salt Reactor Experiment (which went critical in June 1965). The structural material was made to be chemically compatible with molten fluoride salts and capable of being fabricated into complicated shapes such as characterize the containment vessel, piping, and heat exchangers. The only problem with the alloy for possible MSR applications was that, unless modified, its service life would be shortened due to embrittlement from long-term neutron irradiation.

In 1956, Hank Inouye, W. D. Manly, T. K. Roche, D. E. Rosson, and G. Golston began development of a modified nickel-based alloy that met such requirements as good corrosion resistance to fluoride salts, good oxidation resistance, moderate strength and ductility at high temperatures, and had the ability to be melted and fabricated into complex shapes which could be joined by welding and brazing. Because chromium is highly reactive with fluoride salts, the ORNL team reasoned that a good alloy base should have the minimum of chromium required for oxidation resistance. Nickel was chosen for the base, with molybdenum to strengthen it at high temperatures, because both are least likely to react with fluorides. To determine the optimum composition, a development and testing program was initiated in which the ORNL metallurgists sought the help of such industries as International Nickel, Westinghouse, Haynes Stellite, New England Testing Laboratory, and Superior Tubing Company. The final composition of the INOR-8 alloy—for which a patent was issued to Inouye, Manly, and Roche—is a nickel base (80% by weight) with 11 to 13% molybdenum, 6 to 8% chromium, and trace amounts (1% or less) of iron, manganese, silicon, phosphorous, sulfur, boron, niobium, and titanium and hafnium.

John Bates adjusts a tunable dye laser, which can be used with the argon-ion laser at the right. These lasers are used to excite Raman light scattering from beta-alumina crystals.

Solid Electrolyte Battery Research

There is a growing effort to develop solid-electrolyte batteries because they are potentially less expensive and capable of storing more electricity per unit weight than are conventional lead-acid batteries. One expert estimates that lead-acid batteries have a power density of 26–33 Whr/kg at a cost of $100/kWhr. By contrast, a sodium sulfur battery would have a higher power density of 220 Whr/kg at a significantly lower cost of $50/kWhr. Solid-electrolyte batteries are now under development at such organizations as the Ford Motor Company and the General Electric Company. Major emphasis has been placed on developing such batteries for powering electric vehicles and for storing electricity during off-peak periods that can be drawn upon during peak-load periods.

John Bates, Jim Wang, Takuji Kaneda, and Herbert Engstrom of ORNL's Solid State Division have been engaged in an informal collaborative research effort with staff members of the GE Research and Development Center in Schenectady, New York, for the purpose of preparing and investigating new materials for the next generation of high power density solid-electrolyte batteries and for the development of a solid hydrogen-ion conductor for application in a high-temperature fuel cell. The ORNL researchers have been studying the conductivity of fast ions through solids in a program originally funded by seed money. The major objective of the research is to determine the mechanism of high ionic conductivity in solids by combining physical properties measurements with model calculations. The research of Bates et al. has focused on the beta-alumina family—a type of crystal having the ideal composition, $Na_2O \cdot 11Al_2O_3$. Sodium beta-alumina is under study because it is the prototype solid electrolyte of the sodium sulfur battery GE is developing. Beta-alumina has been chosen due to its low cost, good mechanical strength, low corrosivity toward the electrodes, and high ionic conductivity.

In a sodium-sulfur battery, positive ions of sodium from one electrode move swiftly through the crystallographically open regions of beta-alumina under the electro-chemical driving force to react with sulfur at the opposite electrode; electrons freed by the reaction are directed through an external circuit giving the battery its power. Other ions that can be conducted through this solid electrolyte with lower degrees of mobility are silver, potassium, and lithium. GE scientists have found that the mobility of lithium can be improved by mixing its ions with those of sodium in the beta-alumina. By laser light scattering and conductivity measurements from beta-alumina single crystals (obtained from Union Carbide's Crystal Products Division), Bates et al. are investigating the increase in conductivity of lithium ions when they are mixed half-and-half with sodium ions. The ORNL physicists are now trying to determine the reason for this enhanced conductivity of lithium, and discussions are being held with GE scientists on the subject. The mixed lithium-sodium beta-alumina has a possible application as a lithium ion conductor due to its potential for making batteries of high power densities.

The ORNL physicists are also studying beta"-alumina (beta double prime) for application in high-temperature batteries and fuel cells and are interacting with GE scientists in this area. This material exhibits a higher conductivity for sodium ions than the beta form and also exhibits an appreciable conductivity for hydrogen ions.

The Purex Process for Fuel Reprocessing

The basis for most worldwide nuclear fuel reprocessing, active and planned, is the Purex process, which originated and had much of its development carried out at ORNL, one of the institutions in the forefront of solvent-extraction science and technology. The ORNL Purex process was developed to recover, decontaminate, and separate plutonium and uranium from nitric acid solutions of spent reactor fuels.

In the Purex process, two immiscible liquids are mixed together. One is a relatively dense aqueous solution containing nitric acid and the dissolved fuel products; the other is a less dense organic liquid containing tributyl phosphate and a diluent. On contacting and intimately mixing these aqueous and organic phases in laboratory test tubes or beakers and larger-scale plant equipment—packed columns, pressed columns, or mixer-settlers—the organic liquid extracts the plutonium and uranium selectively. The organic phase, containing much of the uranium and plutonium, then rises to the top where it can be separated from the depleted aqueous phase below. Multiple stages of the process permit essentially complete extraction of the two valuable metals. Uranium and plutonium can subsequently be separated from each other by changing the valence of plutonium, either chemically or electrolytically, so that these elements then have different extractabilities.

Solvent extraction is a familiar tool in metallurgical and heavy chemical industries, as well as in smaller-scale uses. It is now one of the processes considered in attacking any new separations problem, but it was not so familiar in 1940.

Modern solvent extraction grew up with the nuclear industry, beginning with the discovery that uranyl nitrate is freely soluble in diethyl ether and with the use of ether extraction as a means of purifying laboratory samples of uranyl nitrate.

In 1942, to supply the high-purity uranium required by the Manhattan Project, analytical ether extraction was studied for purification potential and was rapidly scaled up to a heavy-chemical plant operation.

That tributyl phosphate could extract the nitrates of uranium and other actinides was recognized at least as early as 1944. In 1948 and 1949, one of the active problems in the ORNL Technical Division was recovery of the uranium contained in the stored wastes from the plutonium pilot plant. Charles Ellison, Frank Soard, Alan Gresky, and others in the Metal Recovery Group quickly recognized the applicability of tributyl phosphate (mixed with a hydrocarbon diluent) to extract uranium without adding anything besides nitric acid to the waste solution.

Development proceeded quickly, reaching semiworks design by July 1949. The striking success with uranium extraction and decontamination immediately spurred laboratory investigations of changing and selectively controlling the valence of plutonium; its "oxidized" valence state extracted as readily as uranium, while its "reduced" valence state was found to be much less readily extracted, permitting its separation from uranium. These early investigations involved Charles Runion, Willis Baldwin, Frank Bruce, Don Ferguson, Alan Gresky, Frank Steakly, Myron Kelley, and others in the Chemical Technology Division, as well as Ray Stoughton and others in the Chemistry Division. By September, major attention had shifted from waste-metal recovery to the concept of tributyl phosphate extraction of uranium and plutonium from dissolved spent fuel. Then, one day, this concept was christened Purex—for Plutonium Uranium Reduction Extraction—by exuberant developers in the Chemical Technology Division. Present that day in Steakly's office were

Runion, Gresky, Ferguson, and Charles Ellison, among others. The process reached plant operation at Savannah River in 1954 and at Hanford in 1956, and soon thereafter was used in many plants throughout the world.

Plant flowsheets continued to evolve, and the Purex process has been adopted or modified worldwide for the recovery of materials to be used in place of enriched uranium in power reactors. Special applications of the process can recover thorium, uranium-233, and uranium-235.

Currently, there is no commercial power reactor using plutonium as the major fuel; thus, application of the Purex process is still limited to the weapons industry. The process was used for a brief time in plutonium separation at the Nuclear Fuel Services Plant in West Valley, New York, which reprocessed fuel from commercial power reactors and some government research reactors. The plant was shut down for modifications, and subsequent problems with compliance with changed government regulations made it impractical to reopen the plant.

Many other processes have been tested for recovering uranium and plutonium from irradiated reactor fuels, but nothing has been found to replace the Purex process. "If America's nuclear policy regarding the use of plutonium were different," says ORNL's Ray Wymer, "Purex would be in widespread use today."—*Jeff McKenna*

The Value of Subcontracting

In recent years it has become evident that one of ORNL's chief contributions to the local economy has been the spawning of new private enterprises. Frank Bruce, ORNL assistant director for administration, noted in the Spring 1972 issue of the *Review* that 27 local companies had been started by past or present employees of the Laboratory. Several of these spin-off industries actually marketed products based on technologies developed at ORNL—a type of technology transfer from the established laboratory to the fledgling firm. For example, EG&G ORTEC was formed in 1960 to market silicon surface-barrier detectors based on an ORNL development; since then, the company has become one of the largest worldwide suppliers of nuclear and x-ray radiation detectors and electronics for particle and quantum energy spectrometry. Chemical Separations Corporation, started in 1955, continues to sell special water-demineralization equipment using a continuous-ion-exchange contactor invented by Irwin Higgins at ORNL. Other local companies organized to market ORNL-developed technologies include Tennelec, Inc., and Tennecomp Systems.

The presence of ORNL, the Oak Ridge Gaseous Diffusion Plant, and DOE's Oak Ridge Operations is stimulating the growth of the Oak Ridge area economy in another way. Thanks to the substantial increase in

subcontracting of DOE-funded R&D projects to industry (as well as to universities and governmental institutions), a handful of nationally known companies have opened branch offices recently in Oak Ridge to be near the DOE plants where the subcontracted work is managed. These branch offices have hired more than 100 employees, many of whom are local people including ORNL retirees. Like the dozens of other companies that have signed contracts with Union Carbide, Nuclear Division, these firms with local branch offices are working in such research areas as uranium enrichment by gas centrifuges (with ORO, ORGDP, and the Centrifuge Project Office), fusion energy development, and energy conservation.

Lee Akridge talks to a visitor in his office in the Jackson Plaza complex. He is the Oak Ridge representative for TRW-Energy Systems Division. At left, he can be seen conferring with the administrative secretary, Iula Arnold, through the entrance to the company's local offices.

Subcontractors that have ›pened up branch offices in Dak Ridge include Boeing Engi-neering & Construction, Garrett Corporation, Science Applica-ions, Inc. (the local SAI office s headed by Pete Craven, ormerly of ORNL), System Development Corporation (SDC), TRW, Inc., and Exxon. The Knox-ille area is also benefiting from R&D subcontracting; recently, Jnion Carbide has let sub-ontracts to such Knoxville ompanies as Hydroscience Environmental Systems, JBF Associates, and Technology for Energy Corporation (TEC), a pin-off industry started by ormer ORNL employee Bert Ackermann.

In the subcontracting in which ORNL/UCC-ND is involved, ORNL has program manage-ment responsibility for planning a research effort, awarding DOE contracts to implement the plan, maintaining technical and fiscal control of subcontracts, dis-seminating the results obtained, and assisting in the transfer of developed technologies to demonstration and eventual com-mercialization. ORNL/UCC-ND has subcontracts with all the companies that have local offices, except Garrett Corporation and Exxon.

Boeing, SAI, and JBF Associ-ates are working as part of a task force with Brian J. Baxter of ORNL's Metals and Ceramics Division to develop a summary plan for the design of a High-Temperature Gas-Cooled Reactor fuel-recycle facility for the mid-1990s.

SAI has 15 subcontracts with Union Carbide/ORNL in such areas as the potentials for earth-covered buildings; environmental assessments for the National Energy Plan; cost impact of remote vs conventional mainte-nance on fuel-reprocessing plants; collection of data defining energy resources in proposed wilderness areas administered by the U.S. Forest Service; environmental impact statements related to uranium mining and milling; reports on radiological surveys at inactive uranium mill sites in eight western states; survey of the literature on breeder reactor and HTGR safety issues; and a technology and data base assessment for a 200-MW demonstration plant using a fluidized-bed coal combustor.

SDC (the parent company of Mechanics Research, Inc.) has contracts with ORNL in engineering technology, chemical technology, and fusion energy development. SDC is working with Sam Moore to provide support services to continue development on the application of a computer program to calculate stresses in cylindrical pressure vessels with multiple nozzles, with Bill Burch to complete implementation and operation of a project-control system for the Advanced Fuel Recycle Program, and with Phil Thompson to provide engineering support services for the Large Coil Program.

TRW has contracts with the Energy Division to provide input data for the environmental assessment of a DOE solar energy program, to perform an energy-emergency planning study concerning natural gas shortages, and to conduct environmental assessments for the National Energy Plan. TRW also is working with the Engineering Technology Division on coal-conversion systems, chemical and thermal energy storage, and the Critical Components Program.

Hydroscience Environmental Systems of Knoxville has a contract with the Engineering Technology Division on thermal-energy-transport technology. TEC has several contracts with the Engineering Physics Division in addition to its contract to provide technical services and surveillance and diagnostic measurements to the Instrumentation and Controls Division. TEC's contracts with the Engineering Physics Division include evaluations of the pebble-bed HTGR and of sphere-pac fuel analysis as well as performance of a series of shielding and reactor physics analyses for the proposed Clinch River Breeder Reactor Project.

The portion of ORNL's budget that is allotted to subcontracting R&D has grown sevenfold from about \$4.4 million in fiscal 1974 (4% of ORNL expenditures that year) to \$27.9 million in fiscal 1978 (11.5% of ORNL expenditures). About \$11.8 million was spent this year on industrial R&D subcontracts. Some argue that too much ORNL money is being spent outside to buy services and that not enough is being allocated for in-house research, but ORNL officials say that subcontracting R&D to industry is good for ORNL as well as for the economy. Herman Postma, ORNL director, cites two advantages: "On the one hand, spending more extramurally allows us to utilize other national resources—universities and industries—and enlarge our capability; on the other hand, it gives us more flexibility in responding to changing program directions at the Laboratory." In many cases, ORNL is buying services and information from its subcontrators. And in a time of imposed manpower ceilings, it is often necessary for ORNL to rely on the expertise of subcontractors because the experts needed for certain tasks cannot be readily hired. Subcontracting helps keep ORNL employment levels stable; when one research program is replaced with another, the Laboratory is less burdened with the painful prospect of retraining, reassigning, or terminating a group of employees if a growing fraction of the research is done externally by subcontractors.

DOE favors increased subcontracting because (1) it is an efficient way for national laboratories to procure needed services and products, and (2) performance of the research by the industries where the results are marketable can expedite the transfer of the new technology to the consumer. For example, ORNL is guiding the work of a number of subcontractors in the building and testing of the Annual Cycle Energy Systems, for heating and cooling buildings, and in the development of more energy-efficient appliances, such as refrigerators, air conditioners, and water heaters. DOE argues that taxpayers should get a faster return on their support of national laboratories if some government researchers use their expertise to guide research in the private sector.

A tabulation taken recently of companies currently under contract with the Nuclear Division on behalf of ORNL shows a total of roughly 140 subcontracts. Some of the industries that have several contracts with us are Babcock & Wilcox, Bechtel Inc., General Atomic, General Electric, TRW, and Westinghouse. In addition, Technology for Energy Corporation and Science Applications Inc. together hold 22 subcontracts. The largest divisional participation is by Engineering Technology, which manages 44 contracts. Next is Energy, with 42, and Chemical Technology, which handles 12. The remaining contracts are supervised by Fusion Energy, Engineering Physics, Metals & Ceramics, Environmental Sciences, Health and Safety Research, Instrumentation and Controls, and Nuclear Division Engineering. There are a dozen research and development areas which are supported by multiple subcontracts.

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Best wishes to Herman Postma

Jimmy Carter

In an unprecedented historical event for the Laboratory, President Carter visited ORNL on May 22. As he and Laboratory Director Postma met, Ruth Carey, Oak Ridge photographer, took this picture. After receiving a print of the shot, the President autographed it as shown and returned it to Postma.