Oak Ridge National Laboratory

Spring 1979

review

State of the Laboratory—1978

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Volume 12 Number 2 **Spring 1979**

THE COVER: Laboratory Director Herman Postma summarizes the Year of the Visit in his annual State of the Laboratory Address, delivered on January 23 at the Museum of Science and Energy in Oak Ridge. There was standing room only, the conflict with the State of the Union Message notwithstanding. Postma's message begins on the opposite page.

DEPARTMENTS

The *Review* is published quarterly and distributed to employees and others associated with the Oak Ridge National Laboratory. The editorial office is in Building 4500-North, Oak Ridge National Laboratory. P.O. Box X, Oak Ridge, Tennessee 37830. Telephone: Internal 4-7183; commercial (615) 574-7183; FTS 624-7183.

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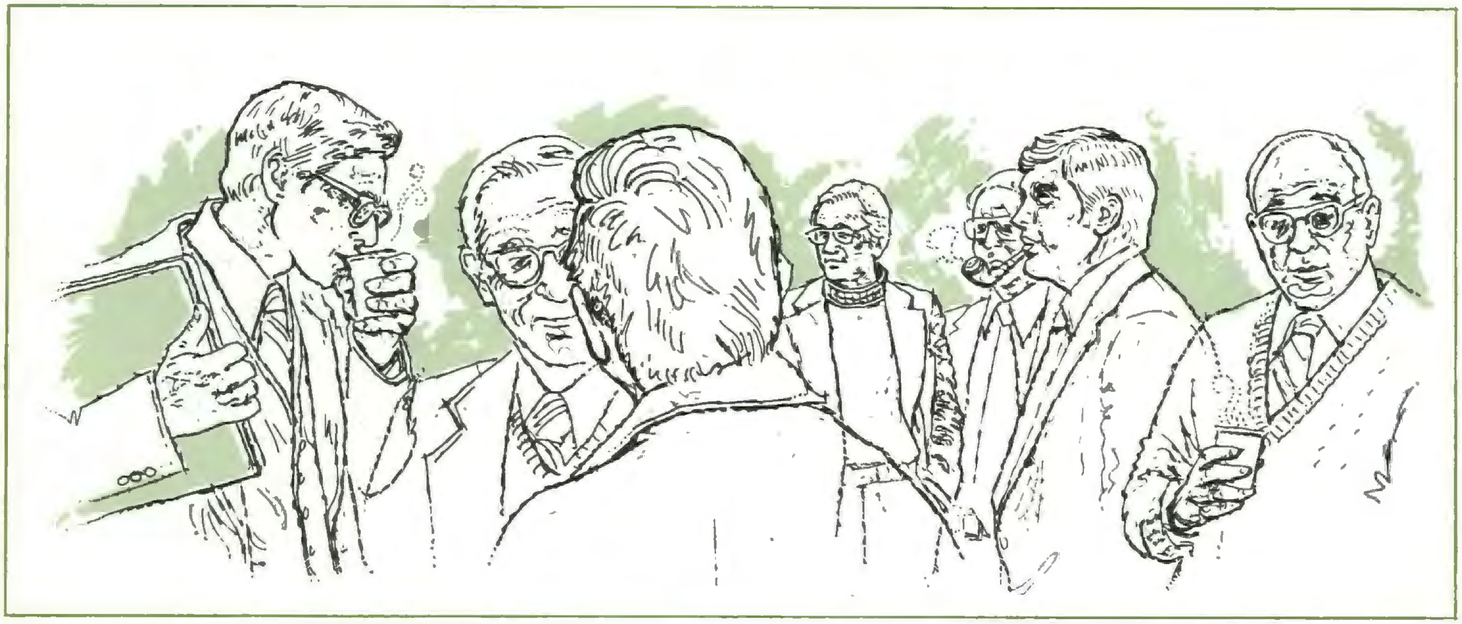


State of the Laboratory-1978

By HERMAN POSTMA

Each year, in summarizing the work of the Oak Ridge National Laboratory or any institution, there is a great temptation to designate "The Breakthrough," or to attempt to find that truly important and revolutionary event that might change the course of mankind. But science really doesn't work that way. What I will emphasize here are many of the ways in which science and technology really do work—a quiet evolution of change rather than the drama of a revolution.

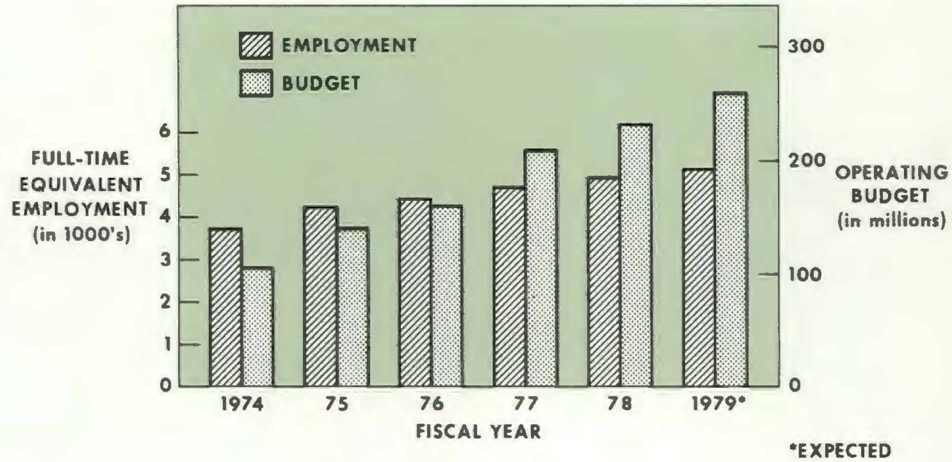
In reality, science builds—usually slowly and always carefully—on prior events. To illustrate that, I had to make difficult choices in selecting appropriate examples from among the more than 700 separate projects carried out by some 5000 professionals and people in supporting roles, for which funding totals almost a third of a billion dollars.

Before covering those selected examples, I would like to give some quantitative indicators of changes and events that have happened at the Laboratory. Then I will turn to some of the past year's findings. Finally, I will try to predict some future events and to provide some ideas of the directions toward which it is important for the Laboratory to move.

The Event

Having expressed disclaimers about really big happenings, I must renege slightly to discuss one very large and important event in 1978. It was not a scientific event—but perhaps it was an engineered one—President Carter's visit on May 22. In retrospect, it was an exciting time, one that brought the science and technology of the Laboratory to the personal attention of the first President to visit us, as well as to the attention of many national politicians, the national press, the scientific advisor to the President, most of the new Department of Energy (DOE) officials, and, inevitably, to the public. Our initial objective was to make sure that the President saw not just what we are doing but also how science and technology help to maintain the national strength of the United States—and how importantly that strength depends upon facts and a rationale, in which science and technology have an important role. I wish to thank all of you who worked very hard to make that visit a suc-

Because an increasing amount of work is done by subcontractors, ORNL operating budgets have grown more rapidly than employment.



cess—those who prepared and presented and all of you who were being represented by those who did the presentations. President Carter made the statement that he was "coming to Mecca." That is flattering—and a high tribute to those whose hard work and contributions throughout the many years of ORNL's existence have given it the worldwide reputation that I believe the President expressed so well.

Some Indicators

The drama and flurry of the President's visit stand in sharp contrast to the many other events and changes that constitute an evolution which occurs quietly at the Laboratory daily, not only visible in science but also evidenced through other indicators. Last year, I attempted to outline some of those changes; this year, I will describe different ones.

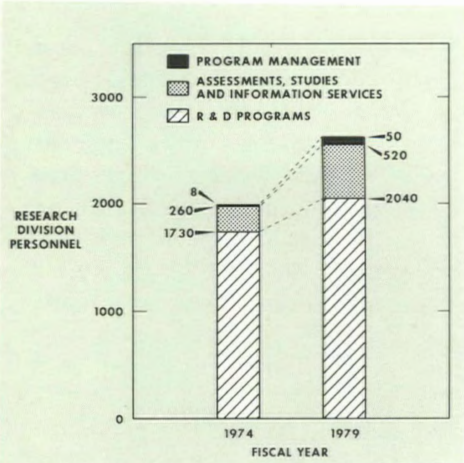
The chief products of the Laboratory are the ideas it has, the data it generates, the papers that are written, the analyses resulting from the data, and the synthesis that comes from compilations and evaluations. These papers, reviews, and assessments cogently represent the Laboratory's ideas, innovations, creativity, and inventions—the focus of "The State of the Laboratory." In spite of the always-impending crunch of paperwork and red tape, and in spite of the incomprehensible amount of information that needs to be handled and synthesized, and in spite of the changes that have taken place at the Laboratory as we have moved into new areas, some of which we are very new at, we find that, in fact, the number of papers published, representing productivity per person for the institution, has remained nearly constant over the last ten years. It is, of course, much harder to measure directly the quality of this work. There are indicators—awards, honors, people nominated for the best papers at meetings, IR-100 Awards—and they have all been increasing in the last few years. Other measures of the Laboratory seen by others concern our ability to set and to meet difficult goals and milestones and to make our commitments come true. When we promise to measure, particularly in the technologies, some important phenomenon, by such-and-such a time and at such-and-such a cost, *and* reach conclusions from such data, we do it! Those goals and milestones have been achieved at a faster rate and at a higher percentage of completion every year. I am increasingly impressed with the degree to which we accomplish what sometimes seems nearly impossible within very stringent time schedules and in very difficult technological areas.

We have also seen a noticeable increase in Laboratory members and staff with particular expertise who are being called for consultation to the Department of Energy, the international energy agencies, the State Department, and particular programmatic areas.

Another trend this year which involves ORNL is DOE's inclination to designate lead laboratories in certain areas. These are areas in which DOE says it will rely upon a particular laboratory as its chief agent of technological competence, programmatic direction, and development of a technological base.

Many years ago, growth in the Laboratory's employment could be linked to growth in money. Recently (and intentionally), monetary growth has not been attended by a commensurate growth in people. This is so because more and more of the work at the Laboratory uses, through subcontracting, the expertise available elsewhere in the country—at other laboratories, in industry, and at universities. As I emphasized last year, that is an area which has grown increasingly and for which we project close to $40 million for the present fiscal year, a factor of 10 greater than that four years ago.

A continuing consolidation is taking place at the Laboratory around fewer themes and in greater depth, particularly in the



The level of effort in paper studies, assessments, and program management is increasing.

new areas of coal and conservation. In keeping with that trend, the shift in the sciences continues from nuclear to nonnuclear in support of those technologies, particularly in areas where we have been given lead responsibilities or into which we wish to move in the future.

Finally, there are other changes that must be viewed in a larger time span than those that have taken place in the last year. Recently, we compared the mix of things we have done in the last five years at the Laboratory from the time of the low point during the year 1974 to 1978, when we reached our maximum diversification, and which marked the end of the period of our most rapid growth and the beginning of consolidation. This comparison reveals the number of people involved in research and development, either experimental or analytical; those who were involved in assessing and studying the results of R&D in order to make evaluations either for assessing environmental impact or for choosing processes; and the degree to which we have been involved in subcontracting in those years. We found that the largest percentage of growth has taken place in program management, but this (50 people) still represents only a small fraction of the personnel (although a lot of money) at the Laboratory. Furthermore, because of the change in the nature of the government funding of R&D and its establishment of priorities, much more effort has been going into studies and evaluations than in the past.

Other Impacts

Other events in 1978 of considerable importance were not so readily distinguished by data and quantitative information. For example, in 1977, DOE was a promise; in 1978, it became a reality. It is already old enough—at least for a government agency—to have changes, reorganization, and the movement of people who are leaving or being reassigned. This year has again been spent in acquainting new people in DOE with national laboratories—with what we do, with how we do it, and with the roles we want to play in DOE missions. It is true that so far DOE has a different view of national laboratories than did its predecessors. DOE feels that the national laboratories have grown too strongly and too fast, and that it is desirable to accomplish more of its missions through working directly with industry rather than through working with the national laboratories. That attitude set the stage for our increased use of subcontracting, program managing, and using industrial capabilities, and for DOE's decision to impose absolute personnel restrictions upon the national laboratories, including ORNL. DOE established a limit of 5150 full-time-equivalent staff for FY 1979, beyond which we cannot go without special permission, regardless of the amount of money that might come to the Laboratory. This, of course, requires some innovative management by all of us as we attempt even more difficult missions under these constraints.

This year also saw ORNL, and national laboratories in general, continue to be much-studied entities. A General Accounting Office report urged that the laboratories be more utilized by DOE. The Buchsbaum report to the President's science advisor, Frank Press, said that the missions of the national laboratories need to be restored and better focused. Congressional hearings were held by the House Science and Technology Committee. At present, we find that the Office of Technology Assessment is looking at national laboratories, and there is yet another in-house DOE study in progress.

There were other events of considerable importance to the future of ORNL last year. Decisions were made with respect to some of the areas in which DOE would count most heavily upon ORNL as its chief laboratory. Bob Thorne, then Assistant Secretary for Energy Technology, wrote this summer, in reply to our 1978 Institutional Plan, that he would designate ORNL as DOE's lead laboratory in the areas of coal technology and nuclear-fuel reprocessing. We have followed up with visits to coal-research centers and with plans for research in materials and other areas. Similar overtures were made by Tennessee Valley Authority Chairman Dave Freeman, who urged that the mutual complementarity of the two institutions be more fully exploited in 1979. We now have a number of joint projects and much more activity under way than we did previously. I believe that this will be truly an important undertaking with TVA as we supply some of the research material, and as they supply the demonstration arena for ideas in a practical sense.

Technical Accomplishments

The true purpose of this annual summary is to provide a perspective on scientific events and technical accomplishments. The Laboratory is an important national institution with many unique strengths and capabilities. One does not have to go very far into a discussion of its work to be enormously impressed by its significance in many diverse fields of basic science and technology. The ability of the people here to think in creative, even revolutionary, ways about scientific and technological problems produces ideas and innovations that have the potential for far-reaching impacts. This process stimulates scientific advances that lead to dramatic changes. There are many outstanding accomplishments that will inspire us all to continue to direct our efforts toward work that will have the most significant long-term impact on the problems we are called on to solve. Although the number of examples I cite here can be multiplied many times over, I hope these important and worthy achievements will speak for all the others.

Cermets for Wastes. In the field of nuclear energy, doubtless the most important issue is the public acceptability of radioactive-waste management. In one year of research, the isotopes research materials laboratory, part of the Solid State Division, has developed a promising long-term primary-storage form for high-level waste. That development, a spin-off of our target fabrication program, is a unique cermet, a combination of a ceramic and a metal. It is prepared by dissolving the waste material and precipitating out all the elements as a homogeneous mixture of oxides, titanates, and aluminosilicates. This mixture is then calcined, compacted, and heated. The final product, an intimate dispersion of ceramic particles in a metal-alloy matrix, has some important attributes, among which is a very high thermal conductivity, about the same as that of titanium, or about two orders of magnitude greater than other candidate waste forms. This alone permits much greater fission-product loading without raising the temperature in the compacted mass because of the heat-transfer properties. The cermets also have a very high density, which means that volume reductions of approximately 70 to 1 can be achieved. Studies now being completed indicate that the rate of leaching of these cermets is even less than for glass or supercalcine, the forms most discussed now. These tailor-made cermets are also highly resistant to corrosion by brine and should perform well at high temperatures and high pressures. Actual nuclear wastes from Savannah River and Nuclear Fuel Services have recently been processed by the ORNL method. The ratio of waste to matrix was 28% by weight. This promising development is certainly timely, since a very recent National Academy of Sciences study urges research in this area.

Microspheres of Fuel. Some of the most important problems we have to resolve in creative ways are nuclear related. There's been much interest in the past few years in greatly reducing the proliferation aspects of nuclear fuel cycles, and a concurrent need to minimize radiation exposure of personnel during any part of a fuel cycle. Members of the Chemical Technology and Metals and Ceramics divisions have been responsible for development of a fuel fabrication process called the Gel-Sphere-Pac—microspheres of fuel which are made from a gel and then packed in appropriate geometry. Besides being easy to fabricate remotely, this fuel has important performance advantages. This year, spheres were created in three different sizes, thus allowing them to be densely packed. The process is well suited for all candidate fuel cycles considered for their proliferation resistance. Especially notable this year has been progress in making uniform spheres, particularly with thorium. The great advantage is that the simplified process is easier to handle in a remotely operated plant. It has none of the milling, pressing, or grinding required in conventional cylindrical fuel pellets, and the feed streams consist of spherical particles that are easily moved around and accounted for. Initial tests reveal less chemical and mechanical interaction between the fuel and the cladding and better heat transfer. This means that reactor-operating time is increased because of greater reliability, and our resource utilization is improved. Industry and utility interest in the Gel-Sphere-Pac process is growing and has resulted in several cooperative programs with potential users.

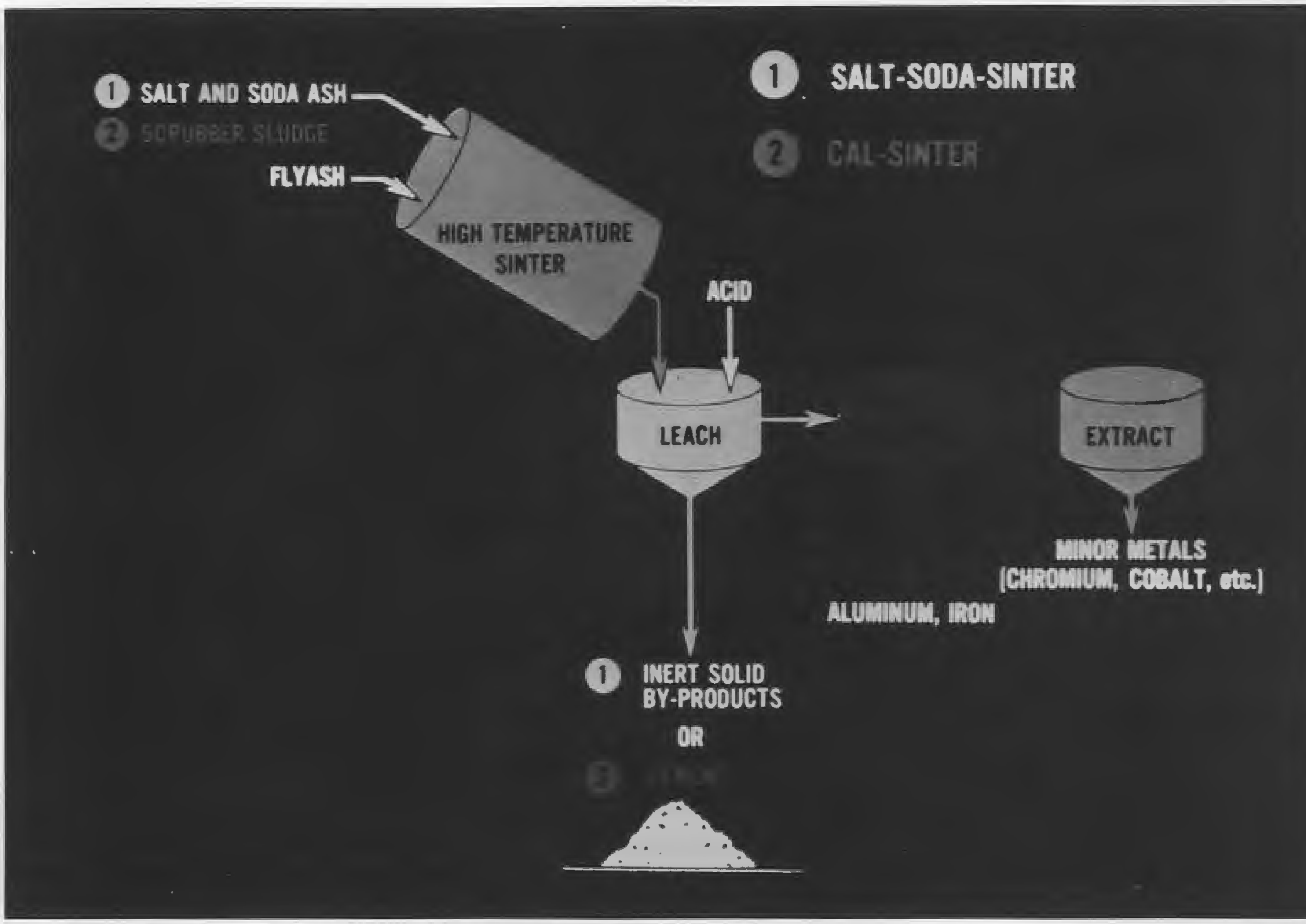
Metals from Fly Ash. A recent law, the Resource Conservation and Recovery Act, placed addi-

Helmut Ringel, guest scientist from Germany last year, observes the formation of uniform beads of nuclear fuel produced by the Gel-Sphere-Pac process developed here.

tional emphasis on the problems of disposal of materials in the ground. The residues from coal burning, such as fly ash, present problems because these immense piles are subject to leaching of toxic materials. They also contain valuable minerals. Coal-burning facilities in the United States annually produce more than 47 million tons of fly ash, which is commonly thought of as being hazardous to health. Researchers in the Chemical Technology Division have discovered ways to recover valuable resources and low-grade ore from fly ash. Two promising processes devised for efficient recovery of aluminum and iron appear to be economic at current product prices and can extract enough aluminum to meet half the current U.S. demand. The processes can recover useful quantities of other metals, including titanium, and can eliminate many of the leachable hazardous pollutants from solid wastes. One of the processes also produces cement. Analysis of fly ash reveals that this material is unexpectedly complex. It consists of glassy spherical structures. Preliminary analysis of one recovery process, the salt-soda-sinter process, has demonstrated an impressive economic advantage as well as resource-utilization benefits from the exploitation of that technology. (See ORNL *Review*, Winter 1979, p. 18 ff.) This can have an important impact on the way we handle waste as well as upon our achieving a dramatic reduction in the volume of hazardous material.

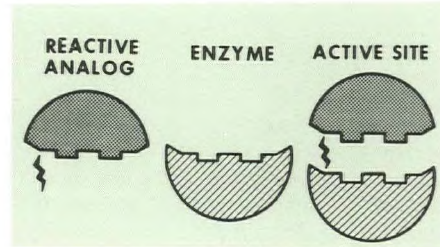
High-Voltage Insulators. Another important example, this one in atomic physics with applications in electrical-energy conservation, pertains to the desirability of reducing the 5 to 10% of power generated that is now wasted through corona losses in high-voltage transmission lines. The high-voltage research program in the Health and Safety Research Division has shown that improvements are indeed possible in gaseous and liquid dielectrics for underground transmission lines, high-voltage switchyards, and substations. A comprehensive program now under way ranges from basic physics, including electron-molecule interactions, to applied testing of simulated practical systems, as well as the environmental impact of short- and long-term uses of these particular mixtures of dielectric gases. The dielectric strength of gaseous insulators can be increased substantially by effective control of the number densities and kinetic energies of free electrons in the basic gas. This results from our basic knowledge that certain molecules capture free electrons more efficiently and that others slow down electron movements through inelastic collisions. The combination of electron scavenging and thermalizing effects suggests that the most practical and efficient gaseous insulators will be multicomponent systems tailored to fit particular needs. Several of those gases and mixtures have been demonstrated, by a factor of up to 2.4, to be superior to the most commonly used gas, sulfur hexafluoride. These gases are reasonably cheap and are being tested under realistic conditions.

Affinity Labeling and Enzymes. Another example of the problems ORNL is solving comes from the biological sciences. Essentially, all of life's processes are dependent upon enzymes that act to catalyze the thousands of chemical reactions which sustain living organisms. The enzyme



Two sintering processes have been invented at ORNL to recover valuable metals such as aluminum from a familiar coal residue, fly ash.

chemistry dealing with these exceedingly complex molecules is a significant basic research area in the Biology Division. The enzymes themselves contain 20 different amino acids and 100 to 1000 individual amino acid units, of which only a small fraction play a critical role in the catalytic process. Innovations and developments have resulted from identification of the active ones, particularly of an enzyme called carboxylase which is required for photosynthetic conversion of atmospheric carbon dioxide into oxygen and carbohydrates. Interestingly, the biologists found that oxygen interferes with a plant's ability to utilize carbon dioxide by inhibiting carboxylase. If that adverse effect could be eliminated, the yield of food crops could be increased dramatically. The technique developed to characterize the active sites is equally important. Called "affinity labeling," it involves the synthesis of a reactive analog of the enzyme's natural substrate. The reactivity of this analog modifies the amino acid groups at that site and permits their chemical characterization. The design and use of that labeling technique has aroused great enthusiasm among pharmacologists because many of the naturally occurring antibiotics and synthetic drugs act by modifying the active sites of key enzymes. The precise mechanism can now be followed in the actions of such drugs as aspirin, penicillin, and antitumor agents. Affinity labeling provides a systematic approach to the design of new therapeutic agents. This development served as the basis for the selection of Fred Hartman as recipient of this year's Pfizer Award of the American Chemical Society, an honor he shares with several members of the National Academy of Sciences and at least one Nobel laureate.



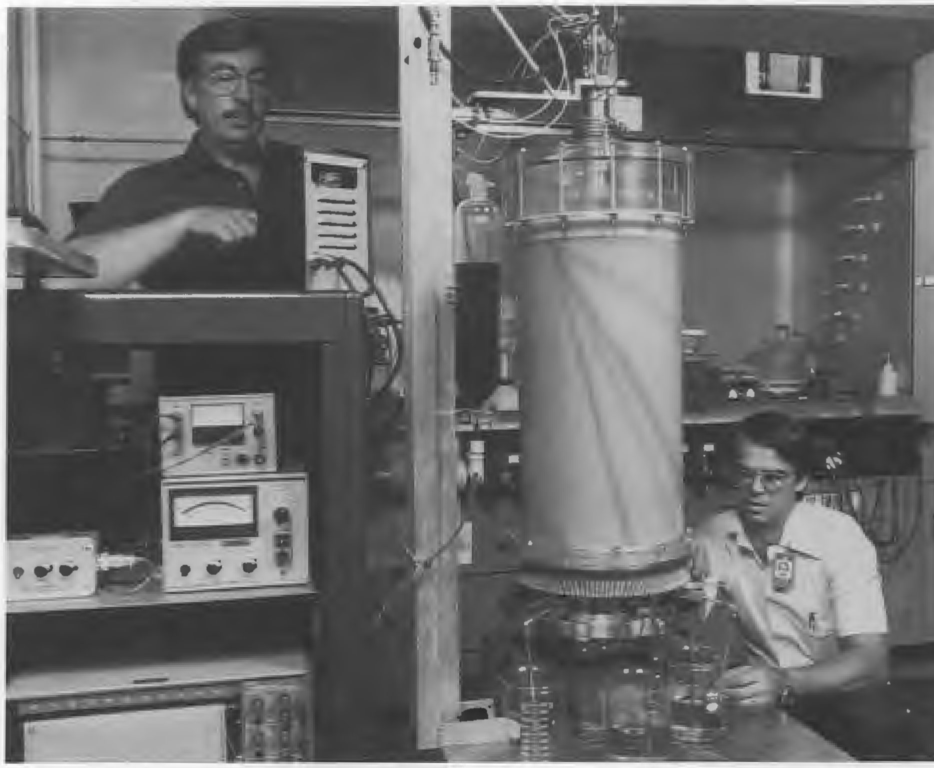
The affinity label chemically modifies the active site of an enzyme, permitting tagging and identification.

Lucile Norton and Fred Hartman prepare to isolate ribulosebisphosphate carboxylase by ion-exchange chromatography. This plant enzyme is essential to the photosynthetic fixation of atmospheric carbon dioxide. It is hoped that basic studies on the enzyme's structure and mechanism will ultimately provide information useful in attempts to improve crop yields.

Basic Energy Sciences

Continuous Annular Chromatograph. One of the ORNL developments honored in 1978 with an IR-100 Award, bestowed by *Industrial Research* upon the year's 100 most important industrial developments, was a unique new tool for separating very complex mixtures. This device, a continuous annular chromatograph, was developed in the Chemical Technology Division. It uses a slowly rotating annulus containing a separation medium in the form of an ion-exchange resin in conjunction with stationary feed and extraction points. The result is a series of helical bands, each of which is a separate mixture component. The device is the first of its type and enables products to be continuously fed, separated, and withdrawn from the column. Among the applications for which it is being considered are food and drug preparation, nuclear-waste-management separations, and resource recovery from liquid-waste streams.

Lasers and Solar Cells. Last year, there were two important ORNL developments related to the efficiency and fabrication of solar cells: neutron-transmutation doping of silicon and the development of a laser technique to anneal damage created by ion implantation in semiconducting devices. This year, the Solid State Division has continued to be at the forefront of an immense international research effort which is rapidly following ORNL's lead in the areas of laser annealing and laser-induced diffusion in semiconductors. Solar cells of 15% efficiency have been fabricated from ion-implanted, laser-annealed silicon, and cells of nearly comparable efficiencies have been obtained from a far less costly method in which the dopant material, such as boron, is merely deposited on the surface and then blasted into the bulk material by the laser-induced diffusion. This latter method bypasses the expensive ion-implantation step and is easily adapted to highly automated cell processing; it has excited considerable interest in the photovoltaic community. On a less applied level, fundamental studies have opened avenues in understanding precisely what happens when one uses lasers to anneal surfaces. They have confirmed and refined



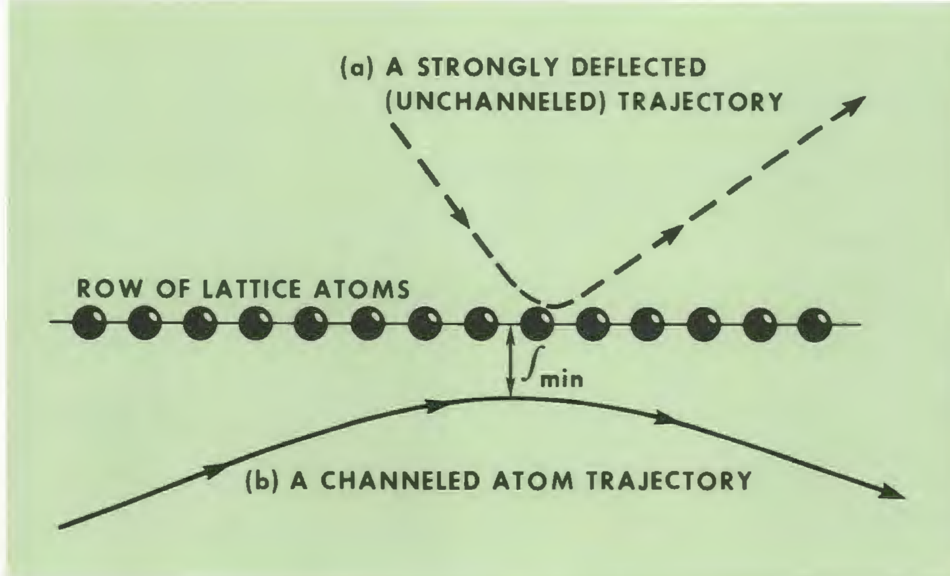
Warren Sisson, left, and Ron Canon attend to the operation of the continuous annular chromatograph, a unique tool they helped develop for separating complex mixtures. An IR-100 Award winner in 1978, this development may have applications in food and drug preparation, nuclear-waste separations, and resource recovery from liquid-waste streams.

most of the results that were first reported in the recent Russian literature, and have established a number of new results. Applications of this technique to the modification of the near-surface properties of a variety of metallic, insulating, and semiconducting materials are already under way or planned. It is my hope that the appropriate applications will be rapidly taken over by industry, leading to reduced costs and more efficient silicon solar cells.

Ion Channeling in Solids. The continuing story of discovery in ion channeling in solids at ORNL that began in the early 1960s has had substantial impact on science and technology. This year it again provides an outstanding example of the dynamic relationship between basic research and its application. We have long been concerned with understanding the origin of radiation damage in reactor materials. It was predicted and later verified that the distance an implanted ion travels in a crystalline solid can be greatly increased if it is directed along a major crystallographic axis. This discovery, called channeling, initiated a sharp increase in studies of ion interactions in solids, the essential feature of which is that those particles that are channeled interact only weakly with the individual, bound-lattice atoms. Consequently, the particles have a strongly reduced rate of energy loss and are much less likely to undergo nuclear reactions. It has been shown that with heavy ions from accelerators fission fragments themselves do relatively little radiation damage when going along such channels. The investigations have expanded rapidly along two courses. The constraints imposed on channeled ions provide basic researchers the opportunity to study ion-solid interactions under unique, well-defined conditions. These investigations give new insights into such phenomena as ion-energy loss, ranges of ions in solids, sputtering (knocking off ions from materials), capture of electrons and their subsequent loss, screening of electrons, and multiple scattering. Probably this work constitutes the most significant advance in the understanding of ion-solid interactions since the early work of Niels Bohr. The channeling effect itself has become a valuable new tool for investigating materials properties, for determining atom-lattice sites and radiation-damage defect structures, for measuring nuclear-reaction lifetimes, or for characterizing electronic properties of semiconductors. Members of the Solid State, Chemistry, Health and Safety Research, and Physics divisions all have been involved in these studies. The range of applications seems to be opening ever wider areas which will continue to develop, expand, and create vast new opportunities.

Radiation Damage Studies. Evolving now is a story of similar potential impact related to work in the Metals and Ceramics Division on ion simulation of radiation damage in structural materials. It involves a combination of Van de Graaff accelerator experiments, electron microscopy, and theoretical modeling of such effects. Three years ago, the development through this program of a low-swelling alloy of

Rosa Young tests the efficiency of a laser-annealed silicon solar cell.



Channeled ions interact only weakly with lattice atoms. Channeling—the movement of ions through open regions in crystals—was discovered at ORNL and is being investigated increasingly.

stainless steel for fast-breeder applications was mentioned in the State of the Laboratory address (see ORNL *Review,* Winter 1976, p. 16). As a quick screening device for candidate alloys, 4-MeV nickel ions were used to simulate radiation damage. The simulation was improved when the transmutation-produced gases, helium and hydrogen, were flowed into the damaged region. A dual-beam facility to accelerate nickel ions and to produce the transmutation gases in damage sites has provided a basis for cooperation between ORNL and Westinghouse on Liquid-Metal Fast-Breeder Reactor (LMFBR) materials. Now the M&C Radiation Effects Group has applied a newly acquired, sophisticated, analytical technique using the x-ray emission from electron microscopy to look at those ion-damaged microstructures. By using this method, researchers found silicon congregating near faults and possibly retarding their growth, which may have contributed to the reduced swelling of the alloy. An even more recent development in the ion-bombardment facility is the conversion to a unique triple-beam unit that simultaneously implants both helium and deuterium concurrently with the heavy-ion damage. The deuterons come to rest at the same depth as the helium, re-creating all the essential ingredients for void formation under controlled conditions. The ratios of gas atoms to displacements per atom can be readily adjusted to cover either those that can be expected in breeder reactors or in fusion reactors. This is an especially opportune development for studies of swelling and radiation damage in fusion reactors because the very high generation rates expected cannot be fully duplicated in existing reactors or accelerators. The potential exists also for manufacturing otherwise unattainable alloys, especially for surface-related applications such as improved wear and corrosion resistance, which might be necessary in some of the more exotic energy environments.

Nuclear Physics

Monopole Resonance. Nuclei, like nuclear physicists, move in strange ways, but one predictable way has been that in which neutrons and protons move collectively against each other so that their charge mass-separation forms an electric dipole. This is the "giant dipole resonance" first observed in the 1940s. At ORNL in 1971, the first direct evidence for a nondipole giant resonance came when a quadrupole resonance was observed. Since then, properties of that resonance have been established in a great many nuclei. In 1977, our collaboration with the laboratory at Groningen, the Netherlands, using inelastic scattering of 120-MeV alpha particles on Pb-208, provided the first direct evidence of a giant monopole resonance. An analysis of 60-

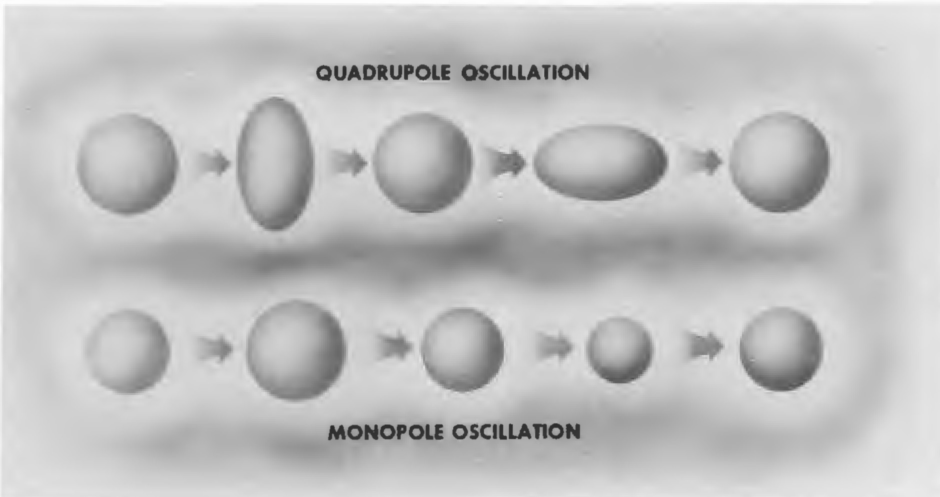
Ray Carpenter observes ion-damaged microstructures through an analytical electron microscope which induces and detects x-ray emission from the object under study. Use of this new technique permits identification and quantification of chemical constituents in radiation-damaged alloys.

MeV inelastic-proton-scattering data taken at the Oak Ridge Isochronous Cyclotron has provided evidence for a monopole resonance in several nuclei of lighter mass. This is especially significant, for the location of the resonance yields a direct measure of the compressibility of nuclear matter, which is very important for understanding heavy-ion collisions. It may lead to an answer as to whether shock waves can actually be excited in nuclei as they are in other matter. If they are, it is possible that such new phenomena as "super-dense" forms of nuclear matter may be revealed. The monopole results support the possibility that we might actually discover such exotic phenomena in the future.

Biomedical and Environmental Sciences

Imaging Diseased Organs. Important spinoffs from nuclear technology have come in contributions to health care and in aids to biomedical and environmental research. With ORAU, ORNL has long been involved in the application of radiopharmaceuticals to the early detection, diagnosis, and therapy of diseases. This year in the Health and Safety Research Division, new and potentially very useful radiopharmaceuticals have been developed and tested for diagnostic and therapeutic applications. In our facility, carbon-11, a positron emitter produced by the 86-in. cyclotron at Y-12, has been used to label amino acids for visual enhancement of images of the pancreas and for tumor localization. These labeled amino acids are being tested in patients at the ORAU Medical and Health Sciences Division, using a tomographic scanning instrument developed at ORTEC. High-quality images of both normal and diseased organs have been obtained in these studies, which have shown that positron tomography can be useful as a clinical diagnostic tool. That same technology has been used to label a widely used antitumor drug, *cis*-DDP, and other drugs, with platinum-195. These agents have sufficient sensitivity to enable us to look at their actual distribution in the body, and even to monitor with *cis*-DDP such specific problems as kidney toxicity. A cooperative program established with UCLA School of Medicine monitors body-fluid levels in patients receiving platinum therapy for cancer of the ovaries. To continue that success story, steroids labeled with tellurium have now been studied in detail for use as imaging agents for adrenal disorders. The adrenal glands of rats, rabbits, and dogs have been very well imaged with these steroids, and preparations are under way with two medical institutions for clinical testing of these new agents in humans. One development with exciting potential is the study of agents that can provide a damage assessment after heart attacks in particular cases. Potassium-43 is a clinical imaging agent originally developed in our program; new agents now under investigation include fatty-acid analogs that have been labeled with tellurium-123 and tin-117m. It is envisioned that these new agents can be used to monitor the metabolic activity in a heart muscle, thereby assessing damage following a heart attack.

Coal Contaminant Detectors. Almost everyone remembers the "cutie pie," the hand-held porta-



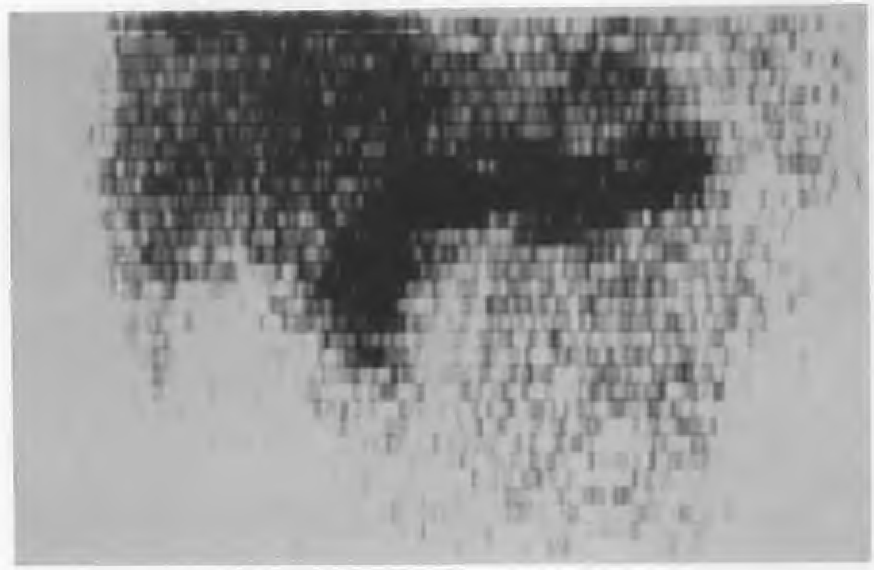
ORNL studies have provided experimental confirmation of giant resonances associated with two fundamental modes of nuclear oscillation.

ble monitor that was one of the earliest and most widely used instruments developed for detecting radioactive contamination. Now in an early stage of development is a very sensitive instrument to detect contamination from hazardous aromatic compounds in experimental coal-conversion facilities. Developed in the Chemical Technology Division, a new monitor based upon a fluorescence detector is sensitive to very small quantities of polynuclear aromatic (PNA) compounds. We expect field testing of prototype monitors this year.

Organic compounds such as the PNAs usually phosphoresce only in a rigid matrix at low temperatures. Therefore, because conventional low-temperature phosphorescence is not practical for field monitoring, a new spectrochemical method has been invented to perform routine analysis both in the laboratory and in industrial hygiene applications. A new approach which significantly improves the analysis of these complex samples uses an external, heavy-atom technique that makes it possible to pick up these special compounds by selectively enhancing room-temperature phosphorescent emission. For example, analyzing synthetic-oil tar now only takes 5 to 10 min, and five major compounds can be identified. It is a simple, rapid, and low-cost method that can be used for quantitative and semiquantitative estimates at a precision which is an order of magnitude better than EPA's criterion of acceptability.

Gene Mapping. Many studies in the Biology Division focus on the carcinogenic, mutagenic, and other effects of coal-derived chemicals as well as those of radiation and other agents. Two developments of fundamental importance to understanding and predicting carcinogenic effects have occurred this year. The first is application of a technique called "gene mapping" to investigate the basis for susceptibility to mutagens and carcinogens. The technique, which involves the use of human-cell or rodent-cell hybrids, permits the identification of individual genes and their assignments to specific chromosomes. Among its applications in cancer research is the genetic dissection of DNA repair mechanisms. We know that cancer has the potential of occurring in many ways, but that repair systems exist to prevent its occurrence. When those repair systems malfunction, the result is the induction of mutations and cancer. The aim of these studies is to identify the number and kinds of genes required for that repair and to assign those genes to specific chromosomes. Other related tasks are the mapping of the gene cells required for tumor virus infection and reproducibility and the establishment of a genetic basis for extrapolating animal data to man.

Cells for Cancer Studies. Currently, our bioassay techniques for identifying chemical carcinogens can detect whether a substance is potentially hazardous, but they reveal very little about which tissues might be susceptible following exposure. In the Biology Division, a model has been developed to determine that specificity. Standard techniques, such as the Ames test which uses a bacterial strain to detect those changes, rely on the addition of liver extracts that activate the test chemicals. The ORNL test uses mammalian cells as target organisms and intact cells from the lungs, the liver, or other organs to activate the carcinogens. This is an improvement over the previous techniques because the intact cells can metabolize carcinogens, which means that we have learned that liver



Positron-emitting, carbon-11-labeled amino acids produce this image of a human pancreas.

cells can activate liver carcinogens, and lung cells will activate lung carcinogens, and so on. Results can be extrapolated to humans when human cells are used, perhaps giving us that vital link.

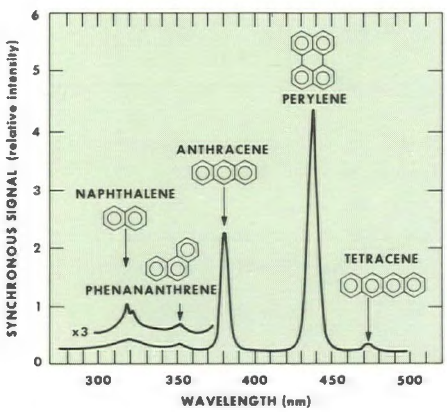
Air Pollution and Vegetation. In an important program in the Environmental Sciences Division, researchers are trying to determine what happens when air pollutants impact upon vegetation. Large acreages of forest and agricultural crops in the United States are exposed to polluted air at levels that may cause damage or may inhibit plant growth. In fact, smog was first identified by its effect on spinach in the Los Angeles area. These air-pollution stresses result from sulfuric and nitrogen oxides, ozone, and rain which is now 10 to 40 times as acidic as normal over much of the eastern United States. To measure those impacts, a controlled simulator and chamber, both designed at ORNL, are used to reproduce the levels and chemical compositions of pollutants to which plants are typically exposed. Studies so far indicate that a significant but apparently temporary reduction in photosynthesis may occur at concentrations less than current EPA standards for sulfur dioxide. In acid rain studies done in a greenhouse, the growth of kidney beans was reduced as much as 10% when seedlings were subjected to rain having acidity levels typical of the Oak Ridge area. On the other hand, in soils that have a deficiency of sulfur, such as those in certain areas of the Southwest, growth may be enhanced by such rainfall.

Studies of Stream Ecosystems. The difficulty of assessing impacts usually depends upon our ability to understand how materials cycle and are transported in an ecosystem. The principle applied to streams is called "spiraling," one spiral being the downstream distance associated with one passage through an ecosystem cycle. Current ecosystem theory suggests that stream ecosystems are adapted to minimize the spiraling length for limited nutrients, and streams with shorter spiraling lengths are more resistant to perturbation and recover more quickly. Experiments at our Walker Branch watershed were designed to test those two hypotheses. The release of a labeled sample of phosphorus to the watershed permitted an experimental determination of the spiraling length for this element which is on the order of 300 m. The significance of this result is not only to establish that there is a finite distance associated with the transport and cycling of this key nutrient, but also to provide a yardstick for assessing the effects of both natural and manmade perturbations of streams.

Energy Conservation

Insulation Tests. One of the newest roles we've had is program management. Our work on DOE's national program on insulating materials and the thermal properties of buildings seeks to improve the understanding of the effectiveness, safety, and acceptance of different types of insulating materials currently in use and to establish overall standards for their performance. Tests developed by the physical properties group in Metals and Ceramics have been designed to measure the resistance to heat flow, air infiltration, and other characteristics of both blanket and loose-fill insulations. This has required development of a number of new test devices and instrumentation. Among them is a method for determining the settled density of loose-fill cellulosic insulation, which recently was chosen by DOE and the Consumer Product Safety Commission as the standard.

Elie Huberman is testing tumor-causing agents in cell culture. His assistant, Cathie McKeown, works at the hood.



Five different aromatic compounds are identified in a synthetic-oil-tar sample with room-temperature phosphorimetry.

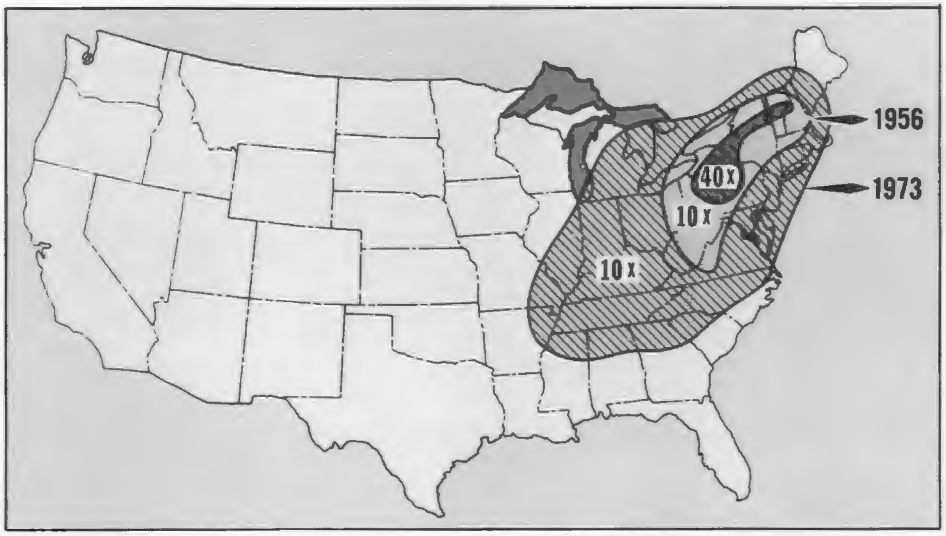
Energy-Efficient Appliances. While we do essential in-house research in our program management areas, most of the work is subcontracted. It is significant this year to see two important subcontract developments in conservation which, because they already have directly affected the manufacturing process, should soon lead to more energy-efficient consumer appliances. The first is a high-efficiency refrigerator-freezer that affords major energy savings without sacrificing any of the convenience features important to users. The refrigerator-freezer operates with less than half the energy allowed under existing minimum energy-efficiency standards. Because of efficiency improvements such as an improved evaporator design and control system, this appliance retains such features as automatic defrosting while reducing power consumption. The payback period for any additional costs of improvements appears to be very favorable.

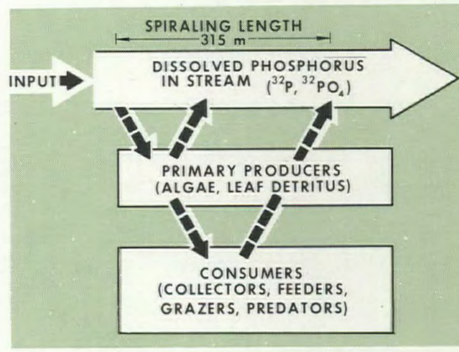
Under the same consumer-appliance program in the Energy Division, a subcontractor has developed an electric-heat-pump water heater that is expected to use only one-half to one-third the energy of conventional electric water heaters. Built in January 1977, the first unit has been tested now for more than a year. In a series of field tests to begin this spring, the water heater will be installed by utilities in 100 homes across the country—a major step toward commercialization. It is expected to cost about $250 as an add-on to existing water heaters and could pay for itself in energy savings in one to five years, depending on individual circumstances.

Fossil Energy

One of our main fossil-energy R&D efforts is the atmospheric fluidized-bed system for the clean combustion of high-sulfur coal. This technology also represents a major thrust for the Laboratory in new cooperative research efforts—with TVA, with the Energy Technology Centers at Morgantown and Pittsburgh, Pennsylvania, and with potential industrial users of this technology who seek to reduce their dependence upon oil and natural gas.

Fluidized-Bed Coal Combustion. Recently, an agreement was reached by which we would supply analytical and experimental support to TVA in their effort to design and build a 200-MW(e) demonstration steam plant fired





Rainfall acidity has increased over large areas in the eastern sector of the United States.

Watershed studies have established spiraling length phosphorus in a stream ecosystem.

by atmospheric fluidized-bed combustion. We will help TVA in analytical evaluation of emission controls as well as in testing of experimental materials. ORNL tasks will include restart tests and sectional-bed slumping as a way of dealing with fluctuations in load demand. These tests will be performed with a 4 × 4 ft cold model. Sulfur capture and carbon loss will also be studied in a newly developed bench-scale combustor system. This system, now ready for operation, represents an important milestone this year. A 10-in. diam. 15-ft-tall fluidized bed has been designed to burn a small amount of coal, use limestone, and operate at an appropriate fluidizing velocity in order to give us operating experience and provide design data in support of TVA's demonstration plant. This device has been built as a joint effort of the Engineering Technology, M&C, and Engineering divisions. It will include fluidized-bed testing, coal combustion, heat transfer, and materials compatability studies up to 1600°F.

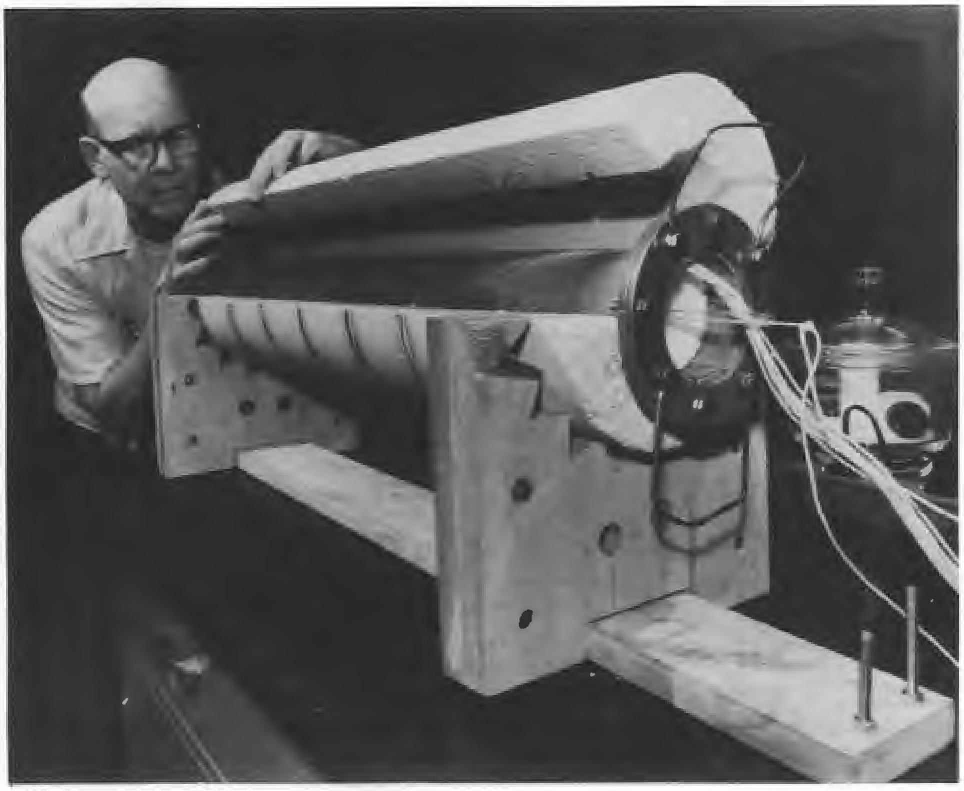
We will be cooperating with Morgantown in additional programs on fluidized-bed combustion, with emphasis on materials testing and the design and construction of a 1.5-MW demonstration "cogeneration" system for which proposals are now being solicited from industry.

Coal Cleaning by Magnets. This past year, an embryonic activity to determine better ways to clean coal before it is burned inspired a reexamination of magnetic beneficiation. Improvements using a high-gradient magnetic separator found that small particles normally present in coal usually result in the agglomeration of the much larger particles, thereby actually impeding the separation of iron pyrites. The small particles can be removed without losing much of the heating value of the coal, and significant reductions in the sulfur and ash content are possible. The objective of our program is to develop this method into a commercial process, not only to help meet the environmental standards but also to reduce the cost of producing electricity. Economic analyses by other people indicate that cleaned coal reduces powerplant operating costs by far more than the cleaning costs. So far the program has demonstrated very satisfactory cleaning: 90% of the BTUs are recovered, and more than 40% of the ash and sulfur are removed. This has been accomplished by using equipment and process conditions which are readily available to industry and which can be scaled up to commercial size. There is interest in larger-scale demonstrations of this technology by TVA.

It is evident that the Laboratory's involvement with fossil energy will continue in the near future to have a major impact on our programs. The designation of ORNL by the Department of Energy as the laboratory responsible for developing the base technology with a focus on eastern coals is one reflection of that growth. We recognize that the growing scope of that involvement in the technologies will require strong supporting research efforts in such areas as coal chemistry and materials sciences, and we are developing programs at the Laboratory to make sure that the research base is available to support the technology efforts.

Nuclear Energy

Reprocessing. The fuel cycle remains the principal focus of the



Fred Weaver examines a mockup of a pipe-insulation tester used to evaluate the resistance to heat flow of insulating materials now in use.

John E. Jones, Jr. (left), and Bob Holcomb work at the atmospheric fluidized-bed combustor (AFBC) bench-scale model. By minimizing discharges of sulfur dioxide and nitrogen oxides, the fluidized-bed concept offers an environmentally acceptable way of burning coal for supplying process heat and electricity.

Laboratory's nuclear work; one significant fuel-cycle development—sol-gel—has already been cited. This year, ORNL was also designated to become the manager of the Department of Energy's Consolidated Fuel-Reprocessing Program, giving the Laboratory primary responsibility for the development of nuclear fuel reprocessing for breeder-reactor fuels in the United States. The program is organized to emphasize the development of technology which is generic or common to several fuel cycles and includes work managed by us but performed at Argonne, Savannah River, and General Atomic as well as at several other industrial and DOE laboratories. Originally, we concentrated on mixed uranium-plutonium fuels from LMFBRs. Because of the change in policy, the scope was enlarged over the last few years to include other candidate fuels, including those based on thorium. The program is deeply rooted in our previous experience in the development of reprocessing methodologies and includes among other tasks basic laboratory and hot-cell testing, component development and testing, and eventual demonstration with hot radioactive substances in the pilot plant. Before then, research and development must focus on providing the technology for building such a hot pilot plant. That effort is now going into an integrated-equipment test facility, to be completed in 1981, which will test in a nonradioactive system all of the components required for remote operation and maintenance of a commercial-scale reprocessing plant.

Reactor Safety Instruments. In reactor safety research, one of the most significant accomplishments this year has come in the Advanced Instrumentation for Reflood Studies (AIRS) program, sponsored by the Nuclear Regulatory Commission (NRC). The goal of the program is to develop and deliver a measurement system for application in several foreign reactor-safety experimental facilities. NRC entered into a cooperative program with agencies in West Germany and in Japan to conduct pressurized water-safety studies to understand the reflood portions of a loss-of-coolant accident. Our role is to develop instrumentation to measure the effects of such an accident. The program was managed by Instrumentation and Controls Division and is supported by significant work in Engineering Technology, M&C, and the UCC-ND Engineering divisions. Sophisticated instrumentation is

Irv Federer (left) and Vic Tennery examine strips of insulating materials and refractory bricks that have been subjected to fuel-oil combustion in ORNL's Refractory Test Facility. They are trying to determine which materials used for furnace linings and other high-temperature applications are the most resistant to deleterious reactions with impurities in fuel oils.

required for measuring two-phase (water and steam) velocity and void fraction. Sensor configurations have been investigated for use in both upper plenum and in-core measurements. Among the challenges has been the development of electronics to make high-resolution measurements of the electrical admittance of sensors over a wide range of conditions; exotic materials that will survive a high-temperature, high thermal-shock environment; welding and brazing techniques; analysis of stochastic signals from sensors using digital processing; and modeling and interpretation of those data. All the development goals were met in a remarkably short time, and the sensors were fabricated and delivered to the test facility. As a result, a whole new type of instrumentation now is available for use in NRC's Reactor Safety Research Program.

Fusion Energy

Perhaps 1978 was the best year ever for the fusion research program in this country. Certainly it was at Oak Ridge National Laboratory. Developments this year mark fusion research as one of our most productive programs. Among the major accomplishments were the recent Impurity Study Experiment (ISX) results which have significant implications for future fusion-power reactors; the development of the first hydrogen "pellet-fueling" system; the beginning of construction on a Large Coil Test Facility; the achievement of high temperatures in tokamaks by using neutral-beam heating devices that were pioneered, developed, and delivered by ORNL; modifications to the Impurity Study Experiment to achieve higher performance; the successful running of the ELMO Bumpy Torus device with modifications; and the selection of ORNL as the host institution for the Department of Energy's Engineering Test Facility Design Center for fusion reactors.

Impurity Study Experiment. The ISX is a collaborative effort between the Fusion Energy Division and General Atomic and is designed to test fusion-reactor concepts and to ascertain the effects of impurities that can get into fusion fuel and that can quench reaction. New developments appeared when the ISX went into operation in December 1977, the most important of which was to produce an extremely long-lived plasma for a low-magnetic-field device due to the plasma's extreme cleanliness. It also achieved high beta—the ratio of the plasma pressure to the combining magnetic field pressure—thereby demonstrating the efficient use of magnetic fields for plasma confinement. The capability of refueling a fusion device with hydrogen pellets was demonstrated, a sophisticated technique preferred in most fusion-reactor concepts. General Atomic researchers working on the device used an advanced technique, called "impurity flow reversal," to keep impurities out of the plasma. The modification of the original ISX to ISX-B, which was successfully completed this fall, includes the addition of neutral-beam injectors similar to those developed by ORNL for Princeton. The ISX-B incorporates a specially shaped plasma, which is a further step in the establishment of

Eugene Hise pours crushed coal into a high-gradient magnetic separator designed to remove inorganic contaminants of sulfur-bearing iron pyrites and ash-forming materials from pulverized coal. This technique for cleaning coal, called magnetic beneficiation, is being developed into a commercial process by ORNL.

economical design criteria. The aim will be to more than double the plasma pressure obtained in the original ISX plasma by changing the shape of the plasma cross section, by adding neutral injection heating, and by using the pellet fueling technique to increase plasma density.

ELMO Bumpy Torus. The ELMO Bumpy Torus confinement concept, now a significant element in the national program, is regarded as the leading alternative to the tokamak and mirror approaches. It has been upgraded through the addition of special high-powered versions of a device called the gyrotron, which produces microwaves to heat the plasma. The ELMO Bumpy Torus now operates at higher magnetic fields and power levels than did the original torus which went into operation some five years ago. The goal is to demonstrate that the principles will remain the same as the plasma temperatures and densities are increased. We are hopeful that the decision will soon be made to build in Oak Ridge an even more powerful version of the Elmo Bumpy Torus as proof of this principle.

Our Large Coil Test Facility is under construction and will be completed in two years. It will test and evaluate six 40-ton, superconducting coils to be furnished by three U.S. manufacturers and by one each from Japan, Switzerland, and EURATOM under a recent agreement. These coils will be very large—15 ft by 12 ft—but only half the size of those expected in early fusion reactors.

Doubtless the most visible success this year in the national magnetic-fusion program occurred at Princeton, where record temperatures were achieved for a tokamak under extreme operating conditions. ORNL shared in that success as the source of the neutral-beam injectors which made that development possible (see article on p. 30). The Princeton test has received so much attention in recent months that little additional comment is required except praise for a job well done, both here and there.

Pellet Fueling. The pellet fueling demonstration, using an injector that resembles a miniature rifle, represents an intermediate step in a series of advanced injectors. This year we created a device capable of injecting a frozen hydrogen pellet—very small, the size of a BB—into a fusion plasma at rifle-shot speeds. The fueling pellet moves across the plasma and is substantially captured without disrupting the plasma. There is a need to refuel fusion reactors, as there is with any other energy system, because the plasma escapes and must be kept at a very high density. The difficulty of this task makes the present accomplishment very important. Pellet fueling was first tested in ORMAK several years ago but did not produce a measurable increase in plasma density. However, devices to produce larger, faster pellets were developed in ISX, and plasma densities were increased by a factor of 2 without any serious interruption of the plasma characteristics. The use of pellets now appears to be an acceptable refueling technique.

Conclusions

It is difficult to project what will happen in science and technology—in 1979, or even tomorrow. It's less risky to discuss those things we can look forward to completing, such as construction

John White (left) discusses with Ned North the scale model of the proposed Hot Experimental Facility, a pilot-scale nuclear-fuel-reprocessing plant. He is pointing to the high-level waste storage tank, which, when built, will be 40 ft tall.

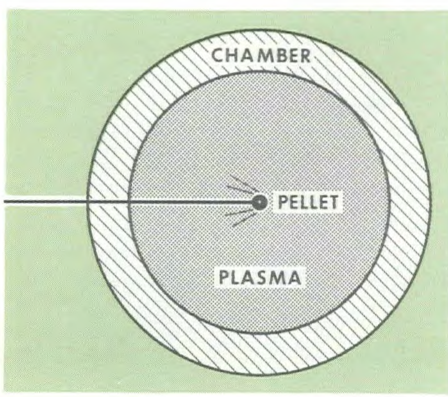
items or large experiments from which important results are expected. In the year just past, we have completed and occupied the new Environmental Sciences Laboratory. In 1979, we will see the final steps taken toward completion of the Holifield Heavy-Ion Accelerator and the user's group beginning work there. The Small-Angle Scattering Facility, sponsored by the National Science Foundation, should be completed. Important results should be coming from ISX-B. A number of other special projects should be ready for commencement of operation.

Although the budget for 1980 is a stringent one, I hope that we have moved in the right directions and with the right emphasis, and that we are now working in the important areas. The cushion of subcontracting developed over the last few years will provide us partial relief in the event that restraint becomes necessary.

In 1979, I anticipate ORNL's having increased responsibilities as a lead laboratory in certain areas—which, I hope, will be the ones we designated in our Institutional Plan. Those decisions will be made shortly by DOE. There will be more emphasis on selectivity in our program commitments—areas in which we will need to plan, to select, and to create priorities within personnel and budget constraints. We must follow up strongly to support our role in coal-technology development by working with the coal-research laboratories at Morgantown and Pittsburgh. This we expect to occur in much the same way that we supplied important neutral-beam support to the success of the Princeton device in the fusion effort, and to General Atomic in the High Temperature Gas-Cooled Reactor.

It is also proper to reflect upon the significance of a number of events that we have encouraged over the last few years. Several years ago, when we pushed very hard for diversification of the Laboratory, we found a receptive atmosphere to that diversification within AEC and ERDA, particularly in those fields in which the expertise of the Laboratory could bring crucial capabilities and talents to bear on difficult problems in a short time. That acceptance and our contributions over the years have been gratifying to me personally, and have produced major directions and changes: From a laboratory that depended strongly on fission and fusion, with a number of supporting sciences, we chose certain directions in coal and

The Impurity Study Experiment (ISX) has been modified to allow researchers to study the effects of increasing the plasma pressure by changing the shape of the plasma cross section, adding neutral-beam-injection heating, and using a new pellet-fueling technique to increase plasma density. Information gained should help engineers evolve criteria for designing smaller, more economical fusion reactors.



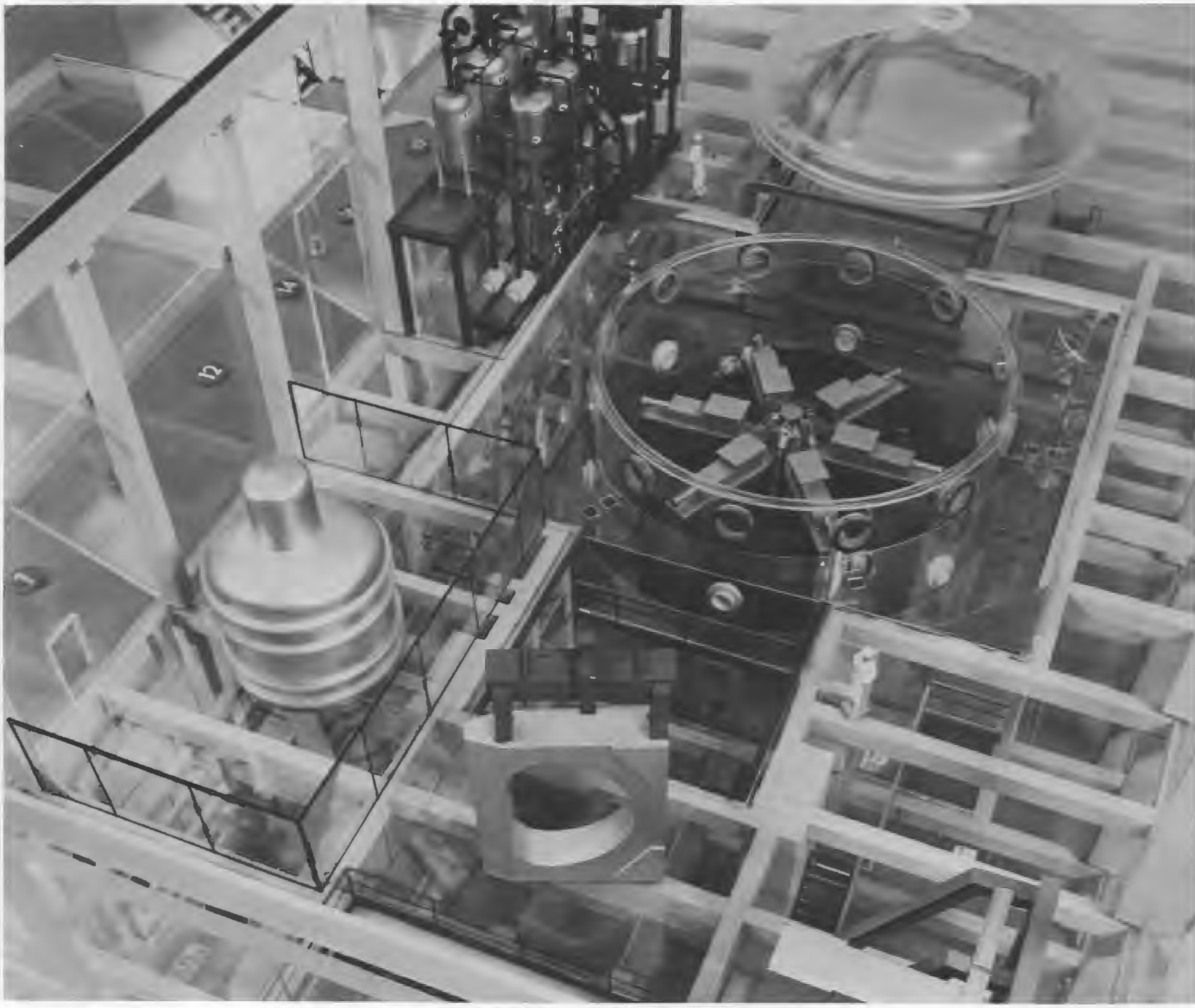
A pellet-refueling technique for fusion reactors was demonstrated with ISX-A. Refueling is essential for maintaining or increasing plasma density.

conservation as our chief emphases because we could bring to bear the kinds of talents that those problems needed. The contributions made by the scientific staff and the acceptance by other organizations of ORNL's role demonstrate that we have truly fulfilled our expectations, although not always in the ways we had initially thought. We have not placed emphasis on solar and geothermal research; instead, we have tried to encourage emphasis on those areas where significant contributions could be made.

During that same time, we encouraged program management and the subsequent subcontracting. We believed with regard to carrying out the missions of ERDA that the Laboratory had special capabilities for managing such programs, for making the best decisions about the kinds of technologies to push, and for monitoring those efforts and judging their outcomes. In so doing, we worked very closely with industry; our subcontracting rose by a factor of 10 during the last four years. On the other hand, to undertake program management we must perform a substantial amount of in-house R&D in those same areas. This is essential to maintain our expertise and keep us at the forefront of such research. We must have existing expertise and capabilities rather than being dependent on something we have to go out and buy. We have to have the say-so—we must make our technical judgments unencumbered by the influences of politics, pork barrel, or other pressures.

I have also encouraged strongly a corporate view of the missions of the Department of Energy, believing that as experts and as technical achievers, we could help when brought in for consultation guide DOE along the correct technical path. However, ORNL did not have to monopolize the work in every case; we have been very cooperative in supporting HTGRs with General Atomic, in working with Princeton to develop beams for their use, and in working with the Energy Research Centers in the coal technology to support their work on research problems by providing the technical backup and depth that have been needed. This cooperation should not exclude the concept of the Laboratory as having principal areas for which it is almost solely responsible: areas in which it performs research for its own use and for technical backup to the decisions of others.

We have also encouraged staff involvement outside the Laboratory. We have urged the establishment of users' groups—teams that can avail themselves of the unique facilities of the Laboratory for the advancement of science or for the support of technological efforts. We have greatly encouraged more involvement with industry, in the form of joint



The Large Coil Test Facility now under construction will be used to test and demonstrate the operation of huge superconducting electromagnets for use in confining plasmas in toroidal fusion devices. The facility, scheduled for completion in 1981, will test six electromagnets constructed by three American firms and three foreign organizations.

projects and of subcontracting R&D, to ensure that the inventions at the Laboratory find their way quickly to the user. A special issue of the ORNL *Review* last year emphasized some of these achievements. We have also sought greater involvement with universities, particularly those in the Southeast; and we anticipate working more closely with ORAU in the future to bring universities in to utilize the facilities and to understand the missions of DOE and the Laboratory. We have also pushed for stronger regional involvement—with TVA and with the Morgantown and Pittsburgh Energy Research Centers, as well as with the universities and the state governments—because of our special situation, being located in the fastest growing part of the nation. We should be very careful to remember that we are Oak Ridge *National* Laboratory and that our missions are *national* in scope.

George Klody, of the National Electrostatics Corporation, stands by the stainless-steel terminal shell which is scheduled to be installed this spring on top of the insulated column of the Holifield Heavy Ion Research Facility (HHIRF). National Electrostatics built the 25-MV electrostatic tandem accelerator for HHIRF.

Having viewed a number of these major directions, we must now think about what might be seen as a consolidation around these themes. We need to maintain strong relationships between the basic sciences and the big technologies. Those areas of technology that we have chosen to emphasize at the Laboratory—fission, fusion, coal, and conservation—need the deep involvement of the supporting physical and life and environmental sciences so that the influences of one impact on the other. That involvement needs, in turn, the correct balance and provision of a technical base for those technologies so that they advance correctly and with assurance.

We need to make sure that in our program management we are developing true leadership, that spokesmen develop so that technological decisions are wisely made and firmly held.

We must ensure that the unique capabilities of Oak Ridge are brought to bear on everything we undertake, that the right balance between science and technology, and that the balance among studies and evaluations and impacts are all made correctly. We must not merely have ideas but the strength and the conviction to carry them forward. We must deal not only with models but also with their validation. We must be concerned not only with impacts, assessments, or evaluations but also with making the necessary measurements. We must make sure that the sciences and the technologies are related. Yet we must keep major portions of the Laboratory concerned with advancing the world of science and taking risks because it is by those who take risks that major developments are made. That balance and consolidation is a challenge for us all; and ORNL is a magnificent, productive, and established contributor to the world's science and technology. It was made that way from your ideas and your hard work and from a spirit of teamwork. That teamwork can be credited with the accomplishments I have described here, and, in fact, with all the work that is being done. That teamwork is made possible by the support and services of so many throughout the Laboratory and the Oak Ridge complex.

To all of you who have made those contributions, I give a special thanks, and a very special appreciation for letting me be part of this magnificent undertaking. ornl

BOOKS

"Proceedings of the Atoms for Peace Awards, 1957-1969—A Memorial to Henry Ford and Edsel Ford," *James R. Killian, Jr., editor. The MIT Press, Cambridge (1978). 304 pages + appendices & index, $15.00. Reviewed by Roy Thoma, technical assistant to Executive Director Clyde Hopkins.*

In what has been termed one of the great speeches of our time, President Eisenhower presented proposals to the United Nations in 1953 "to help solve the fearful atomic dilemma—[and] to devote the United States' entire heart and mind to find the way by which the miraculous inventiveness of man shall not be dedicated to his death, but consecrated to his life."

In 1955, at the Palais des Nations in Geneva, the President expressed the hope" that private business and professional men throughout the world will take an interest and provide an incentive in finding new ways that this new science can be used...for the benefit of mankind and not destruction." Henry Ford's three grandsons, moved by the President's appeal, soon appropriated $1 million to realize this hope through a memorial series of awards that would recognize contributions to the advancement of the peaceful application of atomic energy over the following ten years. Establishment of the Atoms for Peace Awards was announced August 8, 1955, at the first World Conference on the Peaceful Uses of Atomic Energy in Geneva, Switzerland. James R. Killian, Jr., then President of MIT, became chairman of the award committee.

During the following decade, the peaceful applications of atomic energy underwent major development that produced achievements fully as significant as the earlier creation of the weapon. It became apparent that not only could nuclear-power-reactor technology be realized but also with the success of the EBR, designed and constructed by Walter Zinn and his associates at Argonne National Laboratory, mankind for the first time was assured of a practically unlimited source of energy. In retrospect, one might now speculate that this and other great advances in the peaceful uses of atomic energy were partially due to the fact that the visibility of the goal was heightened by the existence of the Atoms for Peace organization.

In this book, Killian has collected the citations, responses, and addresses that were given in each of the award ceremonies. He was impressed, as am I, by "the historical value of the material and the importance of its being brought together in accessible form. Ideas, insights, and information not easy to come by are to be found in this material, and it is interesting to compare the views expressed when the awards were made with current views about nuclear technology and policies." The citations of and responses by the honorees, men whose activities have changed the course of human affairs, give utterance to some timeless perspectives on the human state, and include numerous candid viewpoints of these sages. As such, they collectively form a book that is often profound, and that conveys lucid insights which are refreshing in the face of our currently mixed priorities.

The revolutionary developments occurring within the span of the Atoms for Peace Awards sequence were effected in part by men who, as representatives of the Oak Ridge National Laboratory, brought about significant advances in science and technology and caused the Laboratory to become internationally recognized as a seminal source of such advances. Oak Ridge, which had become widely known as the place of origin of the atomic bomb, became recognized as a major instrument for achieving the peaceful uses of atomic energy. Had such efforts not been championed powerfully, one may pause to wonder whether there might now be a City of Oak Ridge, or for that matter, whether in the absence of the overall benign efforts the use of atomic weapons would have been curbed, and the balance in favor of peace lost, falling prey to excessive violence.

The pathway of peaceful uses of atomic energy is marked with the incandescent achievements of the people honored by the Atoms for Peace Award. The sequence begins with Niels Bohr, whose work in the 1920s set the stage for the unlocked atom; Bohr was followed by de Hevesy, who converted a perceived research failure into success in the form of a new and powerful means for studying nature—radiotracers. His discovery enhanced the wellbeing of people everywhere through almost every field of science, agriculture, and technology.

The third and fourth awards concurrently honored four men who have "done the most to originate and perfect the nuclear-fission chain reactor": Leo Szilard, Eugene Wigner, Alvin Weinberg, and Walter Zinn. In his citation, Manson Benedict commented: "It is appropriate that the fission chain reactor be the central theme of the occasion, because it alone, of all devices thus far conceived, provides a practical means for utilizing the energy of the atomic nucleus and providing radioactive isotopes in abundance. These gifts of the atom, if used wisely, will be of inestimable benefit to mankind."

In 1961, Sir John Cockcroft, whose early discoveries were the first of the now tremendous number of known disintegrations with artifically accelerated particles, was the recipient of the fifth award. As the first director of the British Atomic Research Establishment at Harwell, he can take credit for bringing success to the large-scale atomic energy effort in Britain through an extensive research and development program.

The sixth award was shared by Vladimir Veksler and Edwin McMillan for their independent major discovery that protons and electrons could be accelerated to energies previously thought to be unattainable in manmade devices. Their discovery revolutionized our ideas of elementary particles.

Bertrand Goldschmidt, Wilfred Lewis, and Isodor Rabi shared the seventh award in 1967, not only for their contributions to our knowledge of the nature of the atom but also for their statesmanlike participation in the work of the United Nations Advisory Committee and the International Atomic Energy Agency.

Sharing the eighth award were Sigvard Eklund, Abdus Salam, and Henry D. Smyth for their effort that brought the International Atomic Energy Agency to its present prestigious position. Dr. Eklund was the first director general of the agency; Dr. Salam (whose name means "servant of peace") was the first director of the International Theoretical Physics Centre, which was foreseen as the beginning of an International United Nations University; Dr. Smyth's contributions to the peaceful uses of atomic energy began in 1945, with issuance of his famous report to inform the public of the basic scientific facts of atomic energy. His work continued beyond 1961, through his service as the U.S. representative to the IEAE International Atomic Energy Agency, with personal rank of ambassador.

The elder statesman of the peaceful atom, President Eisenhower, and a relatively younger group of scientists and engineers whose recent achievements illustrate in striking and contrasting ways the beneficial uses of atomic energy, were honored concurrently in the ninth and tenth awards, the last being reserved for the President. The technical group consisted of Aage Bohr, Ben Mottelson, Floyd L. Culler, Henry Kaplan, Compton Rennie, and Anthony Turkevich, who had made contributions to such diverse fields as theoretical nuclear physics, fuel reprocessing, desalination, high-temperature gas-cooled reactors, nuclear radiation and medical applications, and development of nuclear techniques to analyze the surface of the moon.

The publication of this book reminds us of what we had almost forgotten: the importance of identifying and honoring heroes. To continue to forget may make us incapable of recognizing great ideas. The Atoms for Peace concept, and the willingness of world leaders to espouse it, fortunately preceded our present diffidence in the matter of bestowing prestige for achievement. Thus, we have in this small volume a model for our return to the custom of honoring members of society whose efforts have recognizably improved man's prospects for a better life. To accord such honors imposes responsibilities as well. As Dag Hammarskjold put it: "It is, indeed the duty of society to honor such men in words, but it is also its duty to honor them in deeds, by treating the problems of modern man in a way worthy of the advance of knowledge to which they have made such decisive contributions. Thus, it is for society to shoulder its responsibility in the fight against poverty, disease, inequality, and lack of freedom, by the means put at its disposal by science and technology. It is, likewise, the duty of society to shoulder responsibility for the development of ways in which men can live together in this shrunken world, turning the dynamics of change into the stability of peace." ornl

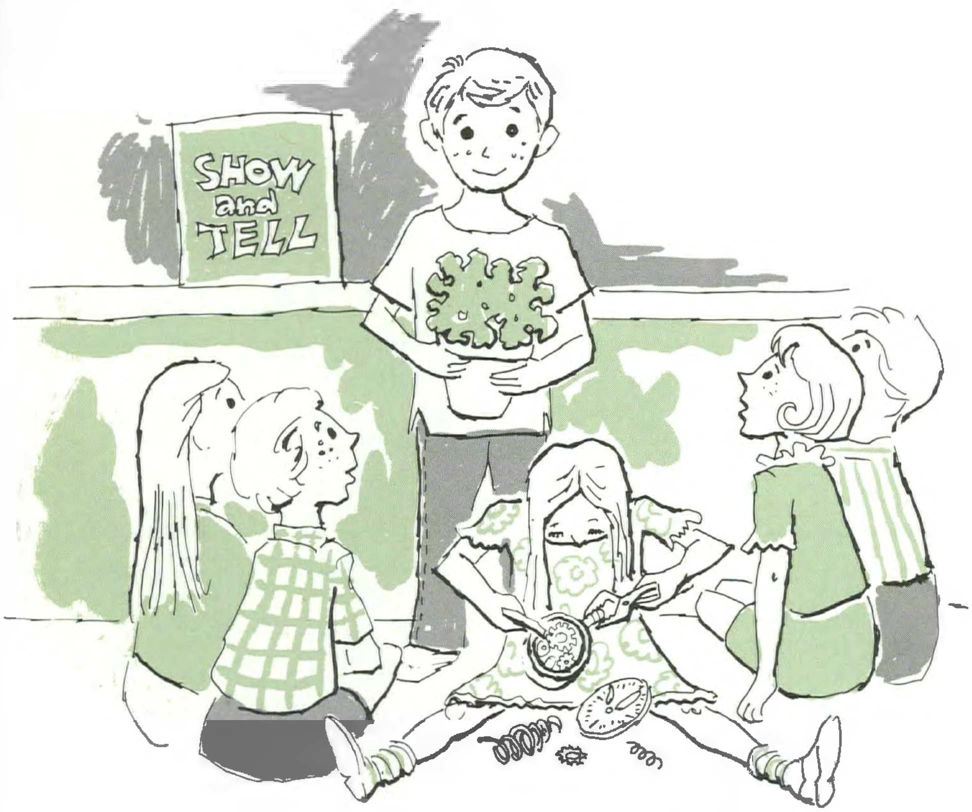
Tom Wilbanks took the job of senior planner in the Energy Division in the fall of 1977, after spending the summer at the Laboratory as a visiting scholar from the University of Oklahoma. His doctorate in geography was earned at Syracuse University, where he was subsequently appointed to the faculty of the Maxwell School of Citizenship and Public Affairs. In 1971–72, he became executive director of the Urban Transportation Institute at Syracuse, and the following year was made research director of the Syracuse-Yugoslav Project on Environmental Policy and Planning. That year he transferred to the University of Oklahoma, where he served as chairman of the department of geography, and later as research fellow in the university's Science and Public Policy Program. This led to his participation in a number of energy-related technology assessments and policy analyses. At the Second Annual Practical Conference on Communications, sponsored by the East Tennessee Chapter of the Society for Technical Communication last fall in Gatlinburg, he was invited to speak on the problems of communication between different disciplines. The following article is excerpted from the talk.

Communications Between Hard & Soft Sciences

By TOM WILBANKS

Let me tell you why I am interested in communications between hard and soft sciences. Basically, it's because I have always thought that academic disciplines are less than adequate to deal with interesting intellectual and social issues. Essentially, disciplines are administrative conveniences—suiting the needs of academic institutions and perpetuating themselves as social organizations. But when it comes to such basic questions as how to assure that people get enough food to eat, or how to assure a stable and secure society, or how to understand the meaning of the universe, these subdivisions get in the way more often than they help out.

It was this kind of point of view that resulted in my choos-



Disinterest

ing to specialize in geography, a field that seemed to close fewer doors than most. Geography has direct links with the social sciences and the earth sciences. Its intellectual sibling is probably physics when it comes to theory building, and its analytical tools are shared with such fields as communication theory, plant ecology, and crystallography.

At the University of Oklahoma, I spent four years as part of the Science and Public Policy Program (S&PP), an interdisciplinary technology-assessment program. At S&PP, I worked every day with nuclear engineers, ecologists, civil engineers, political scientists, philosophers, law school faculty, and many others.

Now, at Oak Ridge National Laboratory, my job mainly involves two goals: (1) to help build a first-rate social-science-research capability in a research institution that has always emphasized the physical sciences, life sciences, and engineering specialities; (2) to help integrate this social science work with the rest of the expertise there.

I have had a real professional stake in communications between the hard and soft sciences—both in trying to talk to them and in trying to understand what they say. And I think the challenges in this kind of communication include overcoming

- Disinterest
- Niche-Seeking
- Acculturation
- Stereotypes

These challenges are substantial ones.

Disinterest

First of all, most people are busy with their own affairs. Their hands are full trying to be good in their specialities, and it's hard to find the time to engage their minds in someone else's field—except as a sort of recreation, if it interests them. In other words, I might be interested enough in "black holes" to read a lot about them, regardless of whether an astronomer wants to communicate with me. But digging into the chemistry of coal conversion, which sounds like work (not fun), might be a different thing altogether.

It's my impression that substantive communication between fields of science is more work than is staying within a familiar community. For one thing, it can involve some costs. For example, the time you spend learning a little sociology to talk to the other person could be spent keeping up with the proliferating professional journals in your own field. Time is one of our most precious personal resources, and allocating it to one kind of communication means that it's not available for another.

So I think the first challenge is that we can't assume that hard and soft scientists consider it a high priority to communicate with each other. They don't object to it, as long as it doesn't interfere with more important things. But they don't get around to it very often, and that doesn't worry them much.

Niche-Seeking

Next, although I wouldn't want to carry this too far, I think that there may be a little bit of self-selection that operates as people choose one field of science over another for themselves. The college student gravitates toward fields in which he or she finds other students who seem to be kindred spirits.

To the extent that this is true, trying to communicate across boundaries between professional groups is like talking to people from a different country or a different culture—people who picked a life that is hard for the communicator to imagine choosing. The campus politicians are all of a sudden trying to talk to those strange people who actually *liked* spending hours in those laboratories, and vice versa. It's not easy, after you get finished covering the weather and the fortunes of the local football team.

Acculturation

The third challenge is professional acculturation. I am convinced that one of the main objectives of graduate school is to train people how to play a particular professional role—how to react to situations. Many times, it's almost a classic example of behavior modification: reinforcement here, penalties there. Unless a person is pretty tough, he or she comes out of all that a *different* person—one who is comfortable playing the role, and uncomfortable operating outside it.

One of the most important parts of the acculturation is learning the jargon of one's own discipline. In a way, jargon is a kind of professional shorthand that speeds up and clarifies communication within the community. But as you know, and as I have found out myself, it's pretty unsettling to try to work professionally in a situation where others not only don't understand your jargon but aren't even willing to grant that it's useful! Communicating from one field of science to another usually requires people to rediscover the regular English language. Yet, we have been trained to think that the regular language isn't adequate for professional work. Although it's our *lingua franca* as citizens, it's not the way we communicate as scientists. So this sort of deeply ingrained attitude makes it harder to communicate with other types of scientists as fellow professionals.

Stereotypes

Finally, there is the problem of stereotypes: the nuts-and-bolts engineer, the narrow-minded physical scientist, or the woolly minded social scientist. We tend to approach people who chose another kind of specialty as representatives of a narrow disciplinary image instead of as the complex individuals that they usually are. We tend to try to communicate in terms of what we think that other person can do, rather than to try to learn more about his or her real interests and skills. But, stereotypes are always too narrow, and they are usually off-target.

These are some of the challenges: People aren't often very interested in communicating; they find it easier and more comfortable talking their own language with people like them; and they often fail to connect with the other person because they are trying to communicate with a stereotype rather than a person.

Such problems are obviously multiplied when a third party wants to communicate with both hard scientists and soft scientists at the same time. Here, the challenges are also complex:

Stereotypes

- Getting Their Attention
- The Perils of Simplifying
- Toe-Stepping
- "You Can't Please Everybody"

Getting Their Attention

Disinterest is compounded when a third party tries to reach two or more disinterested people, and it's even worse when the medium of communication is written rather than face to face. We are all immersed in things to read, when, in fact, very little reading gets done. So coming up with a theme, a gimmick, or something else that will attract the attention of a bunch of dissimilar people is the first challenge.

The Perils of Simplifying

Second, talking to a lot of specialists at the same time means that all jargon has to be

Getting their attention

avoided. But this means using simple language to communicate things that some of the people will think really require complicated language. And, in fact, some of the technical meaning will probably get lost—or distorted a little.

Toe-Stepping

Third, when a third party tries to talk about a cross-cutting subject to a wide range of people, he or she is probably going to step on some toes. Often it's because some of the audience have a vested interest in decisions that the communication might influence. For example, try presenting a balanced summary of the issues surrounding the use of nuclear power in the United States in such a way that nuclear engineers, ecologists, and sociologists will understand one anothers' bases of information and points of view. Almost surely, somebody is going to say that his or her interests have not been represented as strongly or effectively as somebody else's—which brings up the last point...

"You Can't Please Everybody..."

I think it takes more than a little bravery to communicate to a diverse scientific audience. A person has to be prepared to look a little foolish, to be considered a little naive, to be judged as being a little superficial, to take a little criticism.

Well, where do we stand at this point? We have concluded that it is just about impossible to get hard and soft scientists to communicate with each other as professionals, and we have concluded that it is even harder for a third party to communicate with both. Is there any hope?

I not only believe such communication can take place but I have seen it happen, being lucky enough to have participated in it firsthand. Feature this: a group of five people—a nuclear engineer, a systems ecologist, an operations-research specialist, a political scientist, and a geographer—charged with writing a book together about science and technology policy. Nearly two years later, when the time comes to decide what the conclusions are, they find that they not only have arrived at the same conclusions but that they also are speaking the same language, that their thoughts are just about interchangeable, that they no longer can remember which of the ideas in the book started with which person. *That's* communication between hard and soft scientists.

Before I try to draw some lessons from that experience and other evidence, let me quickly indicate some popular approaches that I think *don't* work very well. One is suggesting that one group attend courses to learn about the other. Disinterest and niche-seeking and acculturation are just too much to overcome. What's the incentive, anyway? Another approach is putting together multidisciplinary programs, courses, or research efforts, where each specialist does his or her thing as part of an overall scheme of things. In spite of noble intentions, I think it is very rare for much cross-disciplinary communication to take place—except perhaps inside the heads of students or coordinators. People get busy, do what is required to meet their own specific commitments, and that's all. I have directed a program like that, and I could make it sound truly integrated when I wrote an annual report or a new proposal for funding. But it was really a bunch of independent activities under a fragile umbrella which was largely cosmetic and which existed mainly because of a combination of opportunism and utopianism.

Another approach that doesn't work very well is the introduction of fancy methodologies, including formal group-interaction procedures. People—especially well-educated people—are so aware of being "processed" that they seldom let their guards down to communicate freely under these circumstances.

What does work is some combination of these things:

- Mutual Focus on a Technology or Policy Issue
- Reviews of Draft Materials
- Joint Responsibility for Written Reports
- "Living Together"
  Physical Proximity
  Group Review Processes
  Field Trips
- Exceptional Gate Keepers

This is drawn from the Science and Public Policy Program experience at Oklahoma—truly an epistemological experiment, and a successful one. It reflects a range of other things: the experience of advisory panels for government agencies; a number of successful interdisciplinary policy studies (such as the very innovative National Coal Policy Project, jointly arranged by a senior official of the Dow Chemical Company and a former president of the Sierra Club); the work of the American Association for the Advancement of Science (AAAS) and its remarkable journal, *Science;* and others. There is nothing really amazing about any of these approaches; but they work, and the successes can be documented.

Mutual Focus

First of all, it's necessary to cut across niches and break through disinterest by focusing the attention of both hard and soft scientists on a technology or policy issue to which they all agree is worth paying attention. The issue needs to be complex enough in its ramifications so that everybody can see a way to contribute, and it needs to be important enough so that people are willing to work in some unconventional ways in order to be involved. There are lots of such issues in science policy: energy conservation, recombinant DNA, communication and privacy, quality of urban life, resource scarcity, solar energy—and many more. Basically, you ask everybody to think of himself or herself as, perhaps, an *energy* specialist rather than as a mechanical engineer or as a political scientist. Once everyone redefines his or her niche, even just for awhile, communication is not only possible but also necessary. This, I think, is the secret behind the effectiveness of *Science* and the AAAS.

Draft Reports

A second avenue is to use written materials to communicate—by asking for *responses* to them. I have found that even when somebody in a well-defined niche is busy, he or she will usually read and comment on something you write—*if* you ask *and* as long as there is some kind of overlap of substantive interests—especially if the paper is eventually going to be read by policymakers (such as a biologist when the paper deals in some way with environmental impacts). But there are some secrets to this. You get more feedback if the written materials really *look* like drafts, if they aren't too polished or finished-looking. People want to think they can have some effect on the document, that they can get gaps filled or can remove inaccuracies or mistaken emphases. A polished paper looks as if it's too late for any of this. At Oklahoma, we developed a national reputation for our coffee-stained, dittoed drafts with hand-written inserts, typos, and gaps. It was deliberate, and we got terrific response. Furthermore, once this opened up a communication channel, a lot of the time we could *keep* it open, especially if the next draft showed we had listened to the comments on the first one.

Joint Responsibility

A third avenue is to get hard and soft scientists to *write* something together—not separate contributions to an edited volume, but something that will be jointly authored so that each person is responsible for all that is said. This works especially well if a management process is used that assures a lot of interaction. The way we worked it at Oklahoma was to integrate this joint responsibility with the review procedure. Essentially, a four- to six-person diverse core team is formed to write something about a technology or policy issue. The territory is split up and farmed out for each member to write a rough first draft of some part of it, preferably one that is *not* in his or her

"We need to learn to build bridges..."

area of specialization. Then, each of the drafts is reviewed in detail by the groups—general concept and coverage, writing style, word usage—eventually almost sentence by sentence. It helps if the deadlines for doing the first drafts are so tight that nobody feels that he or she has done anything that approaches perfection. If it's clearly thrown together, nobody's ego gets too tied up with specific wording. Then, you juggle the assignments and have revised drafts written by people other than the ones who wrote them the first time. All along, the group meets to talk about whether the whole thing is moving in the right direction and whether it is subdivided in the right way. These early stages are what we called "the wallowing around period," and it helps if there is time to let it proceed without rushing. As you can see, it is a matter of using the first two avenues, structured just a little and oriented toward a joint publication, to get people with very different professional backgrounds to spent a *great deal* of time together as fellow professionals. I am using a similar approach at the Laboratory now, in order to provide DOE with assessments of the environmental and social impacts of some ideas that are being considered for the second National Energy Plan. The core team includes an engineer, a physicist, an ecologist, a social scientist, and me. Again, it's working very well. We are communicating daily; a lot of the time the communication is intensive, and it's highly professional. I think it is a much more interesting way to work than with one's own discipline alone.

Living Together

I think what I have described is, in many ways, just a structured way to assure this next point: In order to communicate well, hard and soft scientists have to spend a lot of time together—to break down stereotypes, to learn to converse without relying on their own individual jargons, to reorient their definition of niches. An especially effective way to move this along is "field trips"—several people with different backgrounds traveling together, going to see things or to talk to people. The National Coal Policy Project found that it was on long weekends in Montana or in West Virginia, over dinner or in airport lounges, or in the bar in the evening, that the industrialists and environmentalists really started to talk to each other and to identify things they could agree upon.

Exceptional Gatekeepers

Finally, I think we need to recognize that communication between the hard and soft sciences depends a great deal on what sociology calls gatekeepers—exceptional individuals who play a special role in connecting a community with the outside world. There are nuclear engineers, such as David Rose, who talk with theologians. Or economists, such as Lester Lave, who talk with engineers and physical scientists. Or political scientists, such as Don Kash, who talk with earth scientists—people with a special gift for communication and a desire to communicate. I am not talking about the John Kenneth Galbraiths or the Isaac Asimovs or the Carl Sagans, although they help, too. I am talking about scientists who spend a great deal of their time building and maintaining bridges to groups of professionals outside their own fields. You can't program this, and I am not sure that people can be trained to do it. But it is surely possible to encourage and reward it.

We live in a society that isn't working as well as it ought to, and I think the main reason is that we have gotten so compartmentalized. We need to learn to build bridges between all sorts of compartments. The private sector and the public sector need to be able to work together without suspicion and rhetoric. Management and labor should be able to work as partners rather than as adversaries. Ethnic groups and neighborhoods and regions need to understand each others' concerns. All of mankind would benefit by hearing what is being said by all of womankind. Hard sciences and soft sciences as compartments are only one example of a much larger problem, and it behooves all of us to help solve the larger problem as well as the smaller one. ornl

information meeting highlights

INSTRUMENTATION AND CONTROLS, Dec. 7, 1979

TF-30 Op-Amp

Ken Rush reported on the development by his group of a fast, accurate, operational amplifier, the TF-30 Ultra Fast Op-Amp, that was designed to be built into precise electronic-measurement instruments, such as the position-sensitive proportional counter and the Johnson noise thermometer, which require an amplifier with a very wide bandwidth and fast settling. The TF-30, using highly advanced transistors, is a universal gain element that can amplify extremely small signals (as low as a microvolt) to measurable levels with greater bandwidth and less noise than did previously available amplifiers. The broad bandwidth and low noise allow small signal-timing measurements in the picosecond range. Applications for the TF-30 are many, both at ORNL and in industry. It is useful in nuclear-particle spectroscopy, radar-signal processing systems, nuclear-radiation detectors, and in any measurement that requires picosecond timing resolution.—*BL*

ENGINEERING PHYSICS, Jan. 10–11, 1979

Subthreshold Fission Measurements

In 1939, German physicists Otto Hahn and Fritz Strassman discovered that after absorption of a neutron the uranium nucleus could split into two fragments with the release of 200 MeV of energy. This release is the energy source exploited in nuclear reactors and atomic weapons.

Nuclear fission is a very complex phenomenon which is far from completely understood in spite of many decades of experimental and theoretical studies resulting from the importance of this process for the production of nuclear energy. Fission is commonly thought of in connection with the fissile isotopes: uranium-235, uranium-233, and plutonium-239. But fission can be induced in such isotopes as uranium-238, plutonium-240, and thorium-232. Fission measurements of these latter isotopes are being made by researchers at ORNL and at other laboratories.

The fission process is most simply interpreted by the liquid-drop model of the nucleus which was introduced by Danish physicist Niels Bohr in the 1930s. According to this model, forces similar to the surface tension in a drop of water tend to hold the nucleus together, whereas the repulsive Coulomb forces between the charged particles inside the nucleus tend to push apart the components of the nucleus. If sufficient energy is delivered to the nucleus, such as by the absorption of a neutron, the nucleus undergoes large deformations and may eventually fission. These deformed states resemble a football or even a peanut shell.

In ^{235}U, the absorption of a slow neutron (with thermal kinetic energy) provides enough energy to cause a fission. On the other hand, in ^{238}U, a neutron must possess considerable kinetic energy ($\sim$1.5 MeV) if there is to be an appreciable probability of fission. Hence, if one plots the probability of fission (or fission cross section) of ^{238}U against the energy of the neutron causing the fission, one observes a step near 1.5 MeV called fission threshold. Above the threshold, a neutron has a high probability of causing fission; below the threshold, this probability is very small.

In recent years it has been observed that even below threshold there is a measurable probability of fission and that this probability undergoes rapid variations with the energy of the neutron causing fission. A detailed study of the structure of this so-called subthreshold fission has yielded extremely interesting information concerning the forces that hold the nuclei together and the oscillations that the nucleus undergoes on its path to fission. Theorists have depicted these forces in terms of a fission barrier, which, until recently, was assumed to have a single hump. In 1967, Russian theorist V. M. Strutinsky postulated a "double-hump" barrier model, which has proved extremely successful in explaining experimentalists' observations in subthreshold fission.

Because the probability of subthreshold fission is so small, highly specialized equipment is required to study this fission behavior as a function of energy. Groups of physicists from different countries and from different American laboratories have collaborated to measure in detail (i.e., with good energy resolution) the subthreshold fission of ^{238}U, ^{232}Th, and ^{240}Pu. The very high intensity and good time resolution of the Oak Ridge Electron Linear Accelerator (ORELA) time-of-flight facility make ORELA a unique source of neutrons for these experiments. The detector for the ^{232}Th was designed and constructed in France, assembled in Los Alamos, and recently installed on a 40-m flight path at ORELA. The ^{238}U detector, obtained from ORNL's Fusion Energy Division, contains exceptionally pure ^{238}U separated some years ago at the Y-12 Plant.

Researchers involved in making recent subthreshold-fission measurements on ^{238}U, ^{232}Th, and ^{240}Pu at ORELA are G. A. Auchampaugh (Los Alamos), Gerard de Saussure, F. Difilippo (Argentina), F. Gillespie, Jack Harvey, N. W. Hill, R. W. Ingle, D. K. Olsen, Raphael Perez, S. Plattard (France), J. H. Todd, and L. W. Weston. Other measurements, notably on ^{234}U, were done by other groups a few years ago at ORELA.

According to De Saussure: "The high precision and good resolution of measurements done at ORELA in conjunction with other specialized measurements, such as fission-fragment angular distributions done at other laboratories, have led to a much improved understanding of the fission process. However, additional measurements and more accurate calculations of fission barriers are necessary to interpret—and hopefully to predict—the variations of the probability of fission as a function of neutron energy. Rapid progress is being made in that direction."

Working at the personal computer interfaced with the derivative ultraviolet-absorption spectrometer (DUVAS), Alan Hawthorne determines the amount of a specific polynuclear aromatic compound present in an air sample. Pictured in the inset is the DUVAS with air sampling tube. The instrument can detect hazardous compounds in coal-derived gases and tars.

HEALTH AND SAFETY RESEARCH, Nov. 1-2, 1978

Monitoring Instrument for Coal Gases

Products and waste discharges from coal conversion plants include gases, liquids, and tars containing polynuclear aromatic hydrocarbons (PNAs). Because many of these compounds may cause cancer, they pose a health hazard to workers in facilities designed to convert coal to liquid and gaseous fuels. New federal standards should result in a reduction of PNA concentrations in the worker environment in coal facilities. But better instruments are needed to monitor these levels, to assess worker exposure, and to warn workers of elevated concentrations of airborne pollutants due to leaks and other operational problems.

At ORNL, an instrument has been developed that can identify and quantify specific gases and vapors in the workers' atmosphere. Called DUVAS—short for derivative ultraviolet-absorption spectrometer—this portable instrument is the culmination of a year and a half of development work to improve the performance of a derivative spectrometer and to tailor it for pollutant detection.

DUVAS is based on the principle that PNAs and other gaseous, coal-derived compounds each absorb ultraviolet (UV) light of a characteristic wavelength. Thus, if one shines UV light of a known wavelength and intensity through a tube of air containing pollutant compounds and only part of that light gets through to the detector, one can determine which compound is present and its amount based on the intensity of the light absorbed. The second derivative (change in curvature) of the UV-absorption spectrum of a compound is measured, which allows improved selectivity of volatile PNA compounds with overlapping spectral bands.

DUVAS consists of the main instrument package (10" × 16" × 6") and a 1-m tube with mirrors to achieve multiple reflection of UV light. At one end of the tube is a photomultiplier which detects the UV light that has passed through samples of polluted air. Inside the instrument housing are power supplies, processing electronics, a microprocessor to analyze data and correct for interfering compounds, a deuterium UV lamp, and a monochromator that allows a selected wavelength of UV light from the lamp into the air-sampling tube.

The prototype instrument is sensitive to a few parts per billion of PNAs in the vapor phase (such as naphthalene and its methyl derivatives), and it can monitor other important pollutants such as ozone, nitrogen oxides, sulfur dioxide, and ammonia. The spectrometer will be evaluated under field conditions as part of the monitoring program at the low-Btu coal gasifier operated by the University of Minnesota at Duluth. The Tennessee Valley Authority is also interested in testing the instrument for plume monitoring and for fugitive-emissions measurements at their coal-to-ammonia conversion facility in Muscle Shoals, Alabama.

Developers of the prototype DUVAS are Alan Hawthorne and John Thorngate, who is now at Lawrence Livermore Laboratory. Hawthorne, a nuclear engineer by training, is with the Monitoring Technology and Instrumentation Group of the Biomedical Effects and Instrumentation Section, in ORNL's Health and Safety Research Division. Group leader of the Monitoring Technology and Instrumentation Group is Richard Gammage. Mike Dougherty of the Computer Sciences Division assisted with software development.—*CK*

lab anecdote

Out to Lunch

This story was told me by Frank King. Some will remember Frank as an active member of, and frequent actor in, the Oak Ridge Little Theatre, forerunner of today's Playhouse. At ORNL, he was a draftsman and for a while was assigned to the Chemistry Division shop along with an instrument maker and a machinist. If there is no mention here of matrix organizations or field engineers or horizontal integration, it is because those terms were not then in use.

The assistant superintendent of the Research Shops came to the Chemistry shop to tell the three men that their lunches were to begin promptly at noon. The men suggested that they were assigned to the Chemistry Division and should be allowed to eat when the chemists ate and not when the men in the main shop ate.

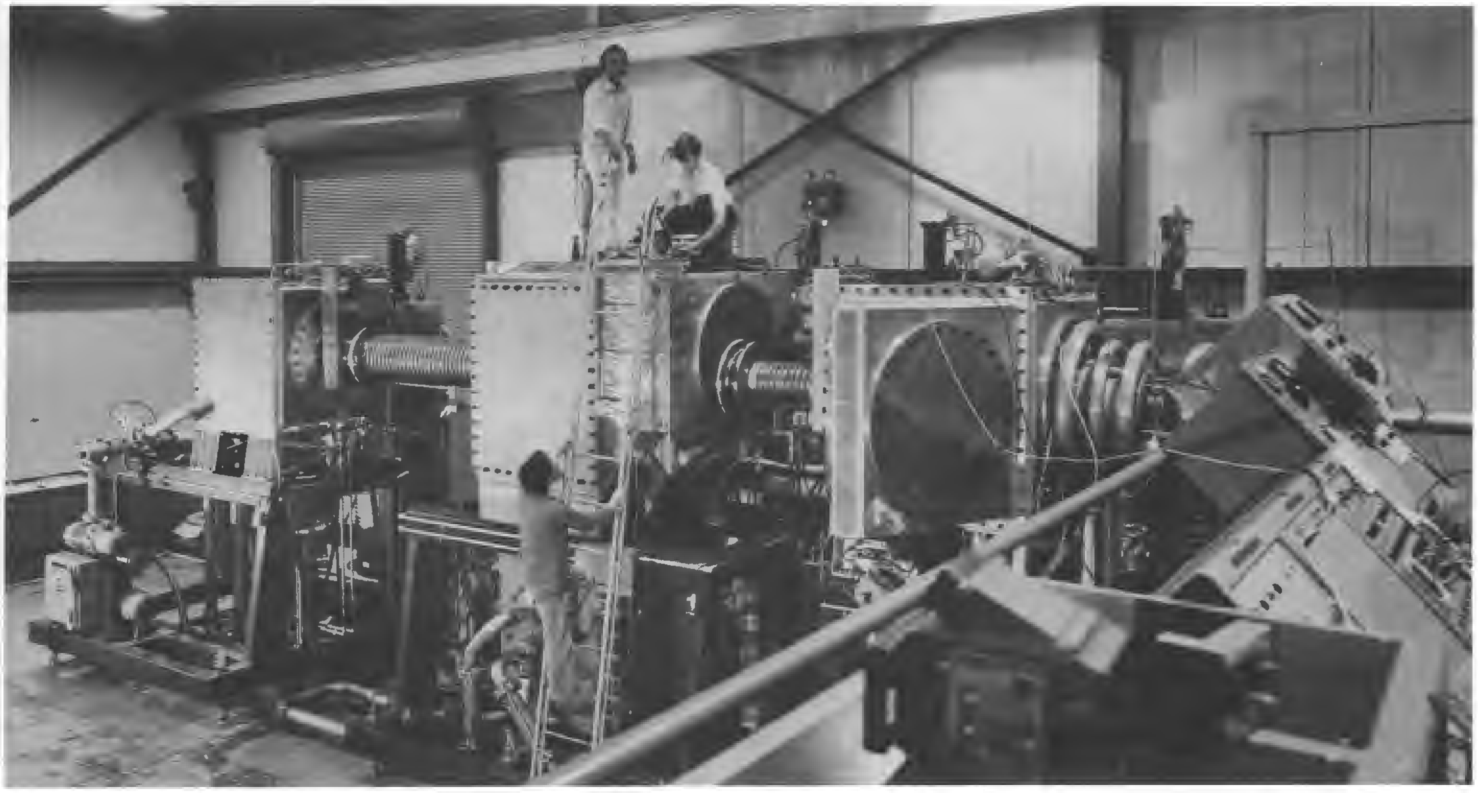
The superintendent of the Research Shops came to the Chemistry shop with the same message and received the same response.

The superintendent's superior, K. P. Wallace, came to the Chemistry shop to tell the men, one by one, that lunch began promptly at noon. Art Mitchell, a 60-year-old instrument maker who was revered by the chemists for his fine work, told Wallace that he owned a house in Florida, and he would just take his wife down to Florida and retire right then if he couldn't eat with his chemist friends on their schedule. The machinist told Wallace a similar story, that he felt responsible to the Chemistry Division, and his lunch time should depend on them.

Frank had heard both stories by the time Wallace got to him. As an actor, as well as a devotee of the elegant variation, he tried another tack. He told his chief that a general could design his own uniform, a major could manage a week off when he wanted it, "and even a sergeant has his little privileges."

No more was heard from the superintendent's office.—*Herbert Pomerance*

Researchers Madhavan Menon, Walt Gardner, and Jinchoon Kim (clockwise from top) work at the High Power Test Facility, which tests new ideas for making powerful neutral beams to heat tokamak plasmas. The ion source is in the chamber on the right, the ion-beam dump chamber is at the center (where the men are working), and the target chamber is at the left.



Doughnut Hotter than the Sun

Reaching Fusion Temperatures with ORNL Neutral Beams

By CAROLYN KRAUSE

In 1978, astronomers observed evidence of a newborn star. If it evolved in the same manner as other stars in the last 20 billion years, its early life story goes like this. Pockets of gas come together by mutual gravitational attraction, forming a gigantic cloud. Under the influence of gravity, this cloud contracts, and the temperature in the interior rises rapidly with compression. The soaring temperature reaches a critical level of 15 million degrees, igniting the hydrogen within the ball of compressed gas and setting off a series of thermonuclear reactions similar to the reactions that occur in a hydrogen bomb. The reactions liberate an enormous amount of energy that prevents the further collapse of the gaseous cloud. A star is born.

Our star, the sun, with an interior temperature of 15 million

Development of neutral beam injectors at ORNL has contributed to dramatic rises in fusion plasma temperatures as well as in the careers of a handful of men intimately associated with the technology.

degrees, bathes the earth with heat and light as a result of thermonuclear fusion reactions. One would suspect that the temperature in the sun's interior would be the hottest temperature attained in the solar system. But in the summer of 1978, researchers at Princeton University in New Jersey used a doughnut-shaped fusion-research machine equipped with neutral beam injectors developed and built in Oak Ridge to achieve a temperature of 60 million degrees, four times that of the solar interior. (Even higher temperatures have been attained in other fusion devices, but many scientists do not view these machines as promising as the toroidal devices for achieving controlled fusion.)

This not unexpected feat at the Princeton Large Torus (PLT) received widespread attention from the news media. It rekindled optimism that devices could be built to harness thermonuclear reactions for producing electricity. The promise of such devices is that they would use fuel that can be found or made in enormous quantities—deuterium, which is readily available from seawater, and tritium, which can be bred from lithium in the fusion reactor. Thus, by learning how to create and control a miniature sun in a fusion device, man has hope of helping the sun provide the earth with heat and light in the next century when other energy sources will be less available.

The successful use of ORNL-developed neutral-beam injection has been the key to the achievement of high temperatures in the PLT deuterium plasma. A plasma is a gas so hot that the electrons have dissociated from their respective nuclei. O. B. Morgan, director of ORNL's Fusion Energy Division, calls neutral-beam injection the "most rapid and significant technological development in the fusion community." Neutral-beam heating has had more impact in achieving high plasma temperature—one of the three criteria for fusion reactions—than has any other in the lineup of heating technologies, including ohmic (resistance) and radiofrequency heating.

Fusion reactions between nuclei of deuterium and tritium (two heavy-hydrogen isotopes) become probable when the plasma temperature approaches 100 million degrees because at such a high temperature the nuclei overcome their electrostatic repulsion and can stick together. This fusion of nuclei results in the formation of a very energetic helium nucleus and a neutron accompanied with an energy release of 17.6 MeV. But producing useful energy requires more than a superhot plasma. The plasma must be sufficiently dense and well-enough confined that enough energy is produced to overcome this energy loss. A density-confinement time product of 10^{14} sec/cm^3 and a temperature of 70 million degrees would produce a condition of energy breakeven—providing as much energy as is used to ignite the plasma. Doughnut-shaped fusion-research devices such as the PLT and the ISX-B at Oak Ridge use magnetic fields to confine the plasma. Historically, it has been a formidable challenge to confine a dense plasma for the required time because the plasma is so unstable. It's a bit like trying to hold jelly with rubber bands.

The PLT and ISX-B are tokamaks, modeled after a Russian doughnut-shaped fusion device. In the late 1960s, both the Russians and Americans had experimented with the torus, the American version of which was called the stellarator. The stellarator used coils to produce two magnetic fields, one within the other, to contain the plasma, and it employed a current in the plasma to heat it by electrical resistance (ohmic heating). In both the American and Russian cases, the torus was part of a transformer with a primary coil to induce a secondary current in the circular plasma. The late Lev Artsimovich suggested to his Russian colleagues that the plasma current should be used not only for heating but also for creating a second magnetic field to help confine the plasma. The Russians called their machine a "toroidal magnetic chamber," or tokamak. After convincing evidence of the good confinement properties of the tokamak was presented at the 1968 International Atomic Energy Agency (IAEA) conference in Novosibirsk, U.S.S.R., the Russian concept was quickly adopted by Americans. In the early 1970s, Princeton converted its stellarator to the Symmetric Tokamak (ST); ORNL built its first tokamak (ORMAK); and other groups constructed other types of tokamaks.

Physicist Walt Gardner checks the operation of the 35-in. diffusion pumps on the High Power Test Facility, which is used to test advanced concepts in neutral-beam development.

Unfortunately, ohmic heating from the plasma current alone cannot produce the high temperatures required for fusion reactions in tokamaks. A supplementary source of heating is needed. "The Russians gave the world the tokamak, and we gave it powerful neutral beams," says Morgan. How Oak Ridge became involved in tokamaks and neutral beam development is related below.

Early History

In 1953, ORNL conducted a small, theoretical study of some possible approaches to the achievement of controlled thermonuclear reactions. The Laboratory's entry into the fusion field seemed warranted by its expertise and experience in the motion of ions in electric and magnetic fields, as in electromagnetic separations of isotopes in calutrons and in high-current cyclotrons. Two years later, small-scale R&D on fusion was started. In 1957, the Thermonuclear Experimental Division was formed, and the Direct-Current Experiment (DCX-1) was constructed. In its first year, DCX-1 successfully trapped in its magnetic field an accelerated beam of atomic hydrogen ions created by the dissociation of hydrogen molecular ions in a high-current vacuum arc. The demonstration raised hopes for magnetic mirror machines, which are linear tubes that use increasing magnetic fields at both ends to prevent the plasma from touching walls or escaping the "magnetic bottle." The experiment showed that ORNL was rapidly gaining expertise in making hydrogen ion beams for fusion research. Work on DCX-1 and later DCX-2 continued well into the next decade.

In 1968, Herman Postma (then director of ORNL's Thermonuclear Division and now ORNL director), Norm Lazar, Gareth Guest, Rodger Neidigh, John Clarke, and Mike Roberts (the latter two are now with DOE's Office of Fusion Energy) visited the Kurchatov Institute in Moscow where tokamak research was being conducted. They came away skeptical of the Russians' favorable interpretations of their results and took only a casual interest in the tokamak scheme.

In 1969, the tide turned for the tokamak. In that year Artsimovich came to the United States and promoted his idea in a series of lectures at the Massachusetts Institute of Technology, and then a British team confirmed the Soviet measurements. At this time, Postma decided that the tokamak scheme deserved closer examination and asked Clarke, Roberts, and George Kelley, now retired, to look into it in greater detail. After discussions with Artsimovich in Boston, ORNL researchers made a proposal presentation in late June to the AEC, which granted approval July 1 and set the stage for construction of a tokamak at

Oak Ridge. That fall, Clarke and Roberts traveled to Moscow and Dubna to absorb more details about tokamak design. ORMAK-1 was born, and Kelley was put in charge of the project.

In late 1969 and early 1970, several ORNL researchers grappled with the difficult problem of making a superhot plasma. According to Mike Roberts in "The Birth of ORMAK: A Personal Recollection" (ORNL *Review*, Winter 1974):

"The tokamak had demonstrated the ability to contain a 'quite warm' plasma, but simple calculations showed that the conventional heating method—by the friction of the electrical current in the discharge—could not make a reactor or a 'reactor-like' plasma. George (Kelley) had thought briefly about the possibility of using energetic neutral beams of hydrogen to add heat, but a rough calculation was discouraging. Director Bas Pease of Culham Laboratory (England), visiting ORNL, urged a more careful look."

Postma also urged a reexamination, so Kelley then performed a more detailed calculation and found that injection was indeed a promising means for providing supplemental heating. Spurred by his discussions with Bas Pease in Oak Ridge, Postma met with Morgan, Kelley, and Harold Forsen (consultant from the University of Wisconsin) and made the crucial decision to proceed with development of neutral-beam injectors. Says Morgan: "We were the first laboratory in the world to commit ourselves to making neutral-beam injection technologically feasible for heating plasmas in tokamaks."

Morgan, Kelley, and others began developing injectors using an ion source that produced a beam of suitable intensity. Their designs are now used worldwide.

Ion Sources and Neutral Beams

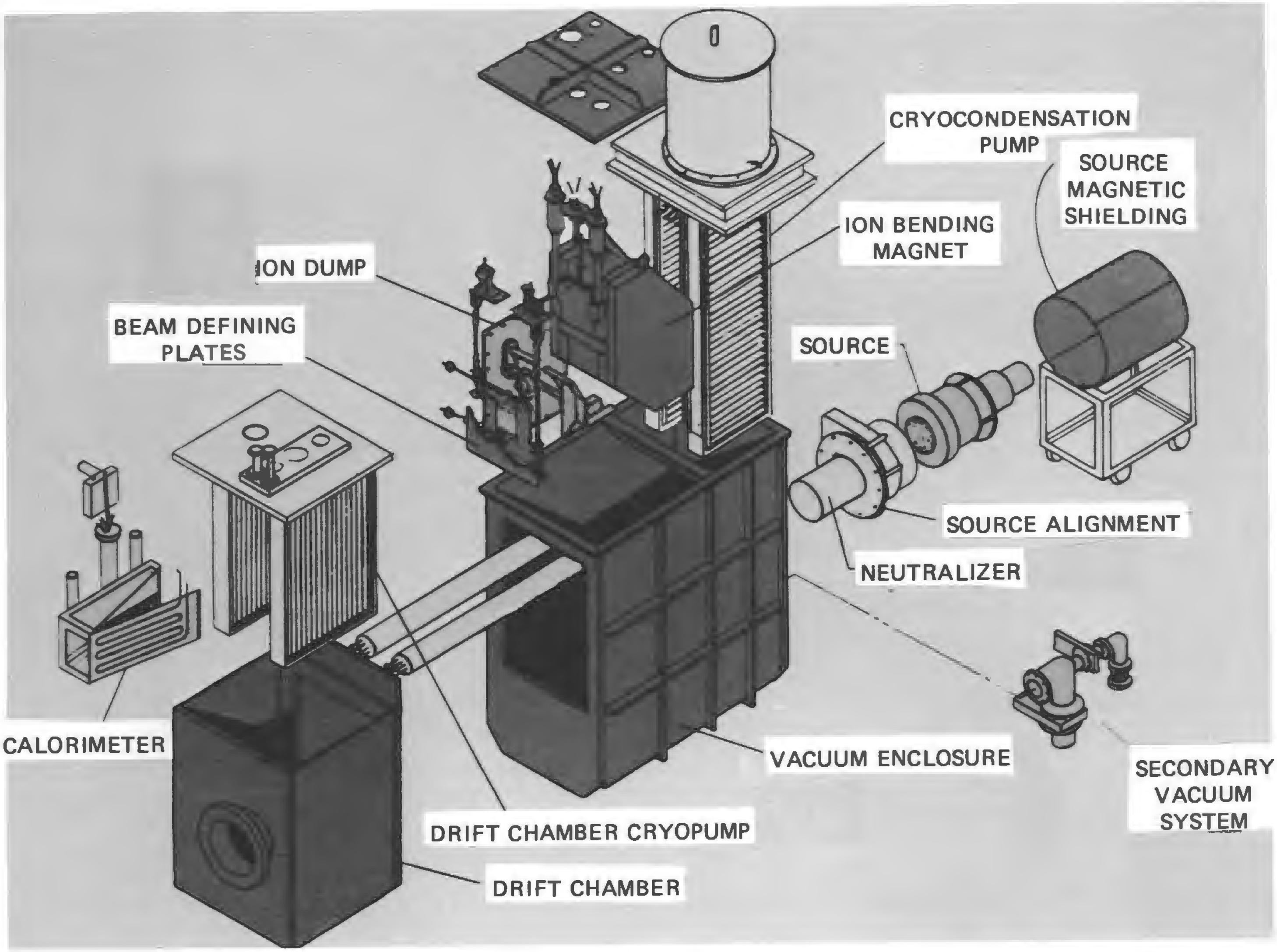
When Morgan came to work at ORNL in 1958, available ion sources included the "duoplasmatron," an East German invention further developed here by Charlie Moak of the Physics Division. Only a few tens of milliamperes of ions could be obtained from these sources. Initially under the direction of Kelley (leader of the Ion Source Group from 1957-67), Morgan set out to improve the duoplasmatron ion source for the DCX. By 1969, Morgan, Kelley, and their colleagues had achieved a tenfold leap from tens of milliamperes to hundreds of milliamperes with an ion energy of 600 keV. Kelley holds a patent on the accelerator configuration, which is still used today.

In the early ion sources, a hot cathode (negative electrode) emits electrons, which flow to the anode (positive electrode). Hydrogen gas introduced into the ion source chamber is ionized—converted to a plasma—by the discharge of electrons, which are collected at the anode. To improve this type of ion source, Morgan incorporated a Phillip Ion Gauge (PIG) discharge by extending the anode region where the electrons can oscillate back and forth between the electrodes in the existing magnetic field rather than die at the anode. Such oscillation is a more efficient use of electron energy to produce hydrogen ions. The magnetic field could also be used to spread out the ions and form a more uniform plasma. Morgan dubbed the modified ion source the duoPIGatron. This was the ion source used to produce the first multiampere beams that showed that neutral-injection heating was technologically feasible.

Why is a spread-out, uniform plasma so important? To get the maximum energy out of the ions for fusion research purposes, it is essential that the ions be extracted from the plasma through many small holes. Kelley explains:

"For the early fusion research machines like the DCX, we needed high-voltage beams. At these high voltages it was possible to get the current required from a single aperture. Tokamak injectors, however, must operate at relatively low voltages—high enough to get the beam particles into the plasma center, but low enough so that the particles don't pass right through the plasma. In this low voltage range it is not possible to extract a large current from the plasma through a single hole because a tiny hole is needed to get a well-defined beam. Since the current per hole is fixed for a given extraction voltage, many holes are required to draw from the plasma a large total current. Thus, the multiple aperture plate was devised to increase beam current."

How does one get neutral beams from an ion source? Ion beamlets are extracted from the ion source chamber and accelerated by an applied electric field (as in a linear accelerator) to form a focused ion beam which enters a chamber containing ordinary hydrogen gas. The ions pick up electrons from the hydrogen gas, forming energetic

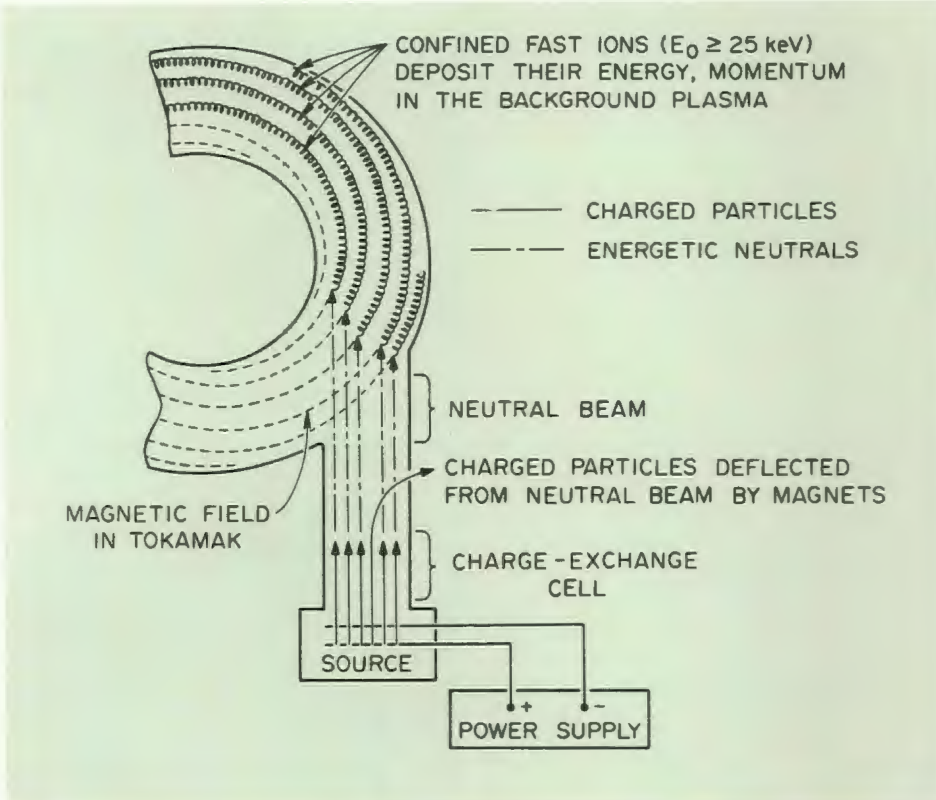


neutral particles. Ions that become neutral atoms can be injected into a tokamak plasma because they are able to penetrate the powerful magnetic field in and around the tokamak. Ions that do not pick up electrons in the chamber are eliminated from further action by a deflecting magnetic field. When the neutral atoms penetrate the tokamak plasma, they can lose their recently acquired electron and then can be trapped in the containing magnetic field while they transfer their energy to the other plasma ions and electrons, thus heating them just as a pint of boiling water poured into a gallon of lukewarm water substantially raises total water temperature. About one-third of the power consumed by the injection system finally appears as heat in the tokamak.

In 1972, Kelley, Morgan, Larry Stewart, and Forsen published the first paper on the subject of neutral beams for tokamak fusion research. The paper, which appeared in the journal *Nuclear Fusion,* is entitled "Neutral-Beam-Injection Heating of Toroidal Plasmas for Fusion Research." Since then, ORNL has continued to improve the ion sources for neutral beam injectors. For example, Will Stirling

The essential components of a neutral-beam injection system are shown here. In this schematic of a PDX beam line, the beam enters the torus at the bottom left.

and Jim Tsai have found other ways to improve plasma uniformity. The duoPIGatron has been continuously modified and has recently had incorporated into it a new type of plasma source which makes use of an invention by Ken MacKenzie of the University of California at Los Angeles. This source uses permanent magnets forming a cusped field around the ion chamber to keep the plasma away from the chamber walls so



This schematic shows how a neutral beam heats a tokamak plasma.

that the electrons have a longer life. ORNL physicists continue to alter the magnetic-field geometry and make other changes with the aim of getting as many amperes of beam current as possible per watt of ion-source power.

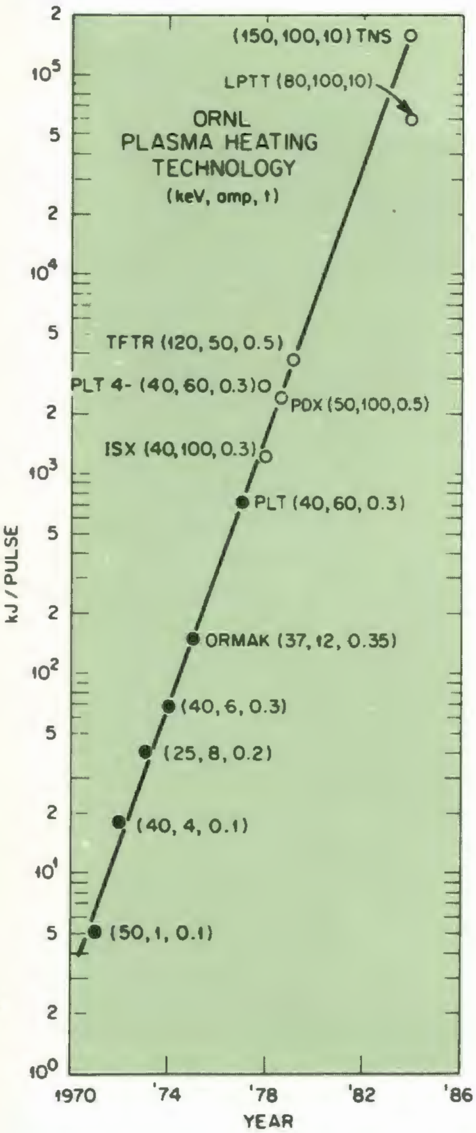
Today's neutral-beam injectors are water-cooled, pulsed systems with ion currents up to 100 amperes each, an improvement of 3 orders of magnitude over the ion sources that Morgan and his colleagues had originally developed. In the past few years, numerous neutral-beam injectors have been built and scaled up in power and energy. ORMAK used four injectors with a total injection power of 500 kW. PLT's four injectors (750 kW each) have a total injection power of 3 MW. The ISX-B has two injectors with a total beam-power capacity of 1.8 MW that will be upgraded to 3 MW by 1980. The PDX at Princeton will have four 1.5 MW injectors by next year. By 1983, the Tokamak Fusion Test Reactor (TFTR) at Princeton will have four injectors, each with three ion sources (to be built by the Lawrence Berkeley Laboratory), for a total beam power of 20 to 25 MW.

ORMAK and Neutral Beams

In 1972, ORNL researchers took the necessary steps to demonstrate that it is technologically feasible to apply neutral-beam injection for heating the plasma of ORMAK, which was then under construction. In 1973–74, the Energetic Particle Injection Group, which Morgan headed from 1969 through 1974, developed neutral-beam injectors tailored for use on ORMAK. At the same time, a group at the Lawrence Berkeley Laboratory, capitalizing on its accelerator experience, developed neutral-beam injectors for Princeton's Adiabatic Toroidal Compressor (ATC). Simultaneously, a group at the Culham Laboratory in England prepared to do injection heating on the Cleo tokamak. Princeton achieved successful plasma heating on ATC in 1974.

Before the experiments in 1973–74, Jim Callen, Clarke, and Jim Rome considered the theoretical aspects of neutral-beam heating. Work began on developing both analytic and computer models to predict effects of neutral-beam injection on tokamak plasmas. (John Hogan and Herb Howe have continued to modify and refine these models.) The theorists worried about whether neutral beams would trigger instabilities in the plasma, and they calculated that it would not matter much whether the neutral beams were injected in the same direction (coinjection) or counter to the direction of the plasma current in ORMAK.

Lee Berry, now director of the Fusion Program, recalls that when the neutral-beam-heating experiments started up at ORMAK, ATC, and Cleo in the summer of 1973, researchers were concerned that the neutral beams might cause the plasma to disappear: "We threw a switch and found that plasma remained. Our heating was several tenths of a percent over what we would get with ohmic heating alone." In 1974, experiments began on ORMAK to determine whether it matters which direction the beam is injected into the plasma. Experiments cast doubt on the theorists' initial estimates. Berry remembers telling



Ion-source development at ORNL has been proceeding as an exponential function of the extracted energy.

Ann Davies, a University of Texas postdoctoral scientist then visiting ORNL and currently director of DOE's Tokamak Section, that counterinjection did not work. Coinjection has been used predominantly ever since.

Following a suggestion by Berry that the counterinjected neutral beam induced fast ions which were more readily scattered and lost from the machine, improved theoretical calculations showed good correlation with the experimental results. The experimental success of modest heating with neutral beams—2 to 3 million degrees—and the difference between coinjection and counterinjection were reported by Berry, Clarke, Jim Lyon, Masanori Murakami, and others at the 1974 IAEA meeting in Tokyo. The theoretical developments and their correlation with the experimental results were presented at the same meeting by Callen, Dick Colchin, Ron Fowler, Dave McAlees, and Rome. An abbreviated account of the combined experimental and theoretical work was published in *Physical Review Letters* in 1975.

ORNL theorists told the experimentalists in 1975 that there should be twice as much heating in the plasma as had been observed. Not enough power from the injection system was getting into the plasma, the theorists said. The experimentalists checked out this assertion by inserting a chunk of metal in ORMAK with attached temperature gauges (calorimeter), injecting neutral beams into the machine, and observing the temperature rise. Seeing that the theorists were right, the experimentalists undertook the task of getting a greater fraction of the power in.

To get steadily larger increments of heating in the ORMAK plasma, the experimentalists made a number of improvements. They expanded the extraction system (number of holes for ion beamlets) and made other modifications that increased the injection power from 50 kW in 1975 to 350 kW in 1976. To increase plasma heating even more, the tokamak researchers removed impurities from the wall by discharge cleaning—running unconfined plasma to scrub the wall. Impurities cause energy losses in plasmas because they radiate away energy. Finally, the ORMAK researchers stepped up the external magnetic field from 15 to 25 kG. By boosting the toroidal field, the researchers could increase the ohmic current and thus get more heating. As a result of these modifications, the ion temperature of ORMAK was raised tenfold from 2 million degrees in 1975 to 20 million degrees in the fall of 1976. ORMAK had achieved a temperature hotter than the interior of the sun. At an IAEA fusion conference at Berchtesgaden, West Germany, Berry reported that ORMAK had attained 2 keV (equivalent to 20 million degrees) of heating, and TFR researchers from France claimed heating to 2.2 keV using duplications of the Oak Ridge ion sources.

How does one measure such a temperature in a fusion device? Certainly not with a mercury thermometer. The chief measurement was made by a charge-exchange neutral spectrometer developed by ORNL's Clarence Barnett and Jack Ray. This instrument measures the energy of fast, neutral hydrogen atoms that seep out of the tokamak plasma, then feeds the data to a computer which calculates results. These neutral atoms are formed by reactions between the hydrogen ions and the small amount of neutral hydrogen at the plasma center. Another way to measure temperature is to use scintillators to count the neutrons emerging from a deuterium plasma because the number of neutrons emitted increases with temperature.

...in early 1977, significant electron heating by neutral-beam injection was first demonstrated...

Since the experimentalists had resolved that coinjection was more effective than counterinjection and had raised the maximum power delivered to the plasma, they next sought to heat the electrons and not just the ions. In tokamaks, the electrons are heated primarily by the ohmic dissipation of the plasma current. Neutral beams deposit a minor portion of their energy in the electrons, but the major portion goes to the ions, which eventually share some of their energy with the electrons. Until 1976, the neutral-beam power delivered to the electrons had been modest compared to the ohmic heating power, and no significant heating by neutral beams had been produced. In fact, researchers in the field were beginning to doubt the ability of neutral beams to heat electrons in tokamaks.

But in early 1977, significant electron heating by neutral-beam injection was first demonstrated in a clever series of experiments, devised by Murakami and his associates, in which the ratio of the injection power delivered to electrons to the ohmic heating power was raised by reducing the ohmic heating current to the lowest possible level consistent with containment of the fast ions. In these experiments it was shown not only that neutral beams could effectively heat the electrons but also that neutral beams could be used interchangeably with the usual ohmic currents to heat and sustain tokamak discharges.

In summary, the plasma heating experiments on ORMAK showed definitively that neutral beams could heat tokamak plasmas. The heating was found to be in substantial agreement with theoretical predictions. The experiments also demonstrated that plasma temperatures substantially in excess of those achievable by ohmic heating alone could be produced with neutral-beam injection. Thus, confidence was gained in applying ever-increasing neutral-beam heating for larger tokamaks, such as the PLT, PDX, and ISX-B.

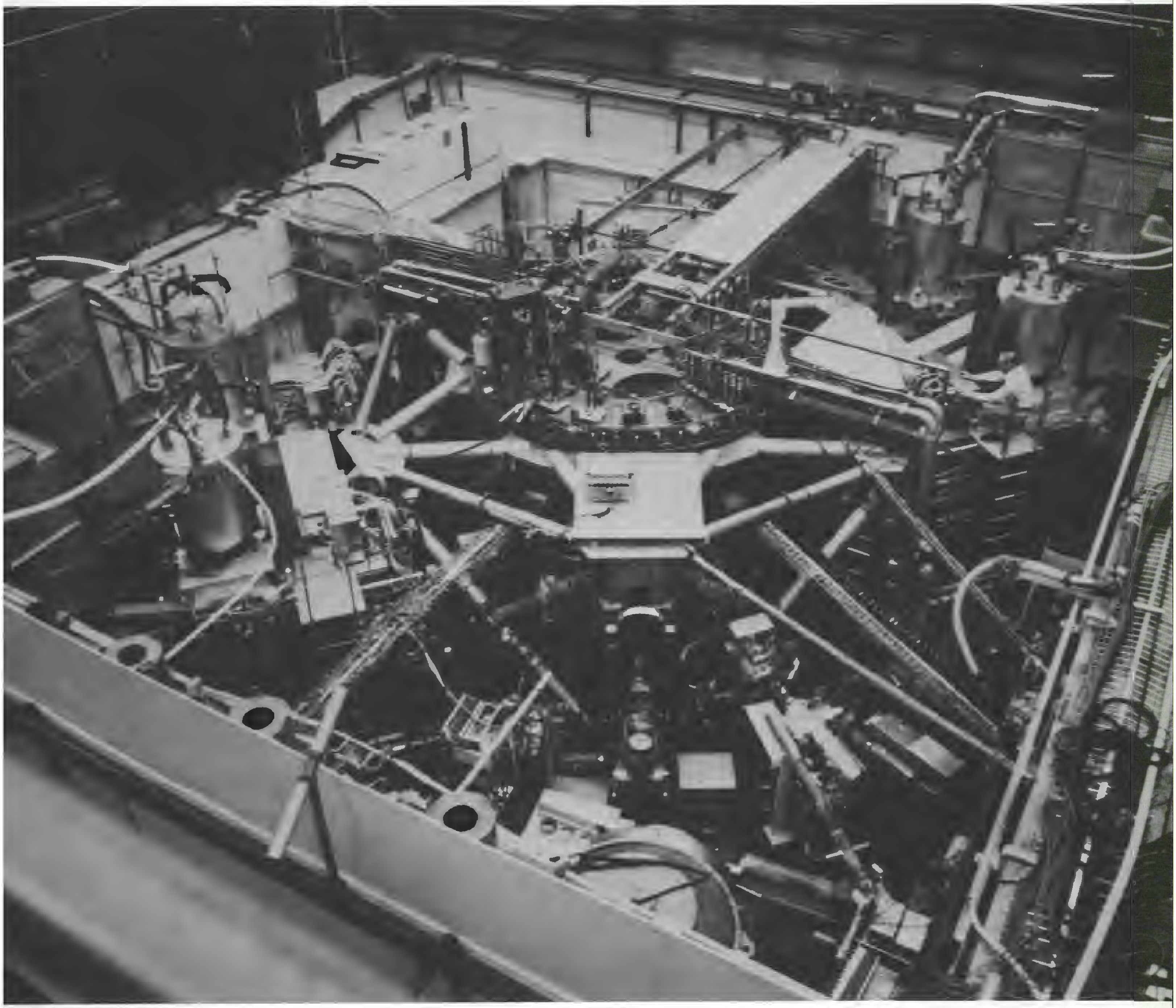
Neutral Beams for PLT

While the PLT was being built in the mid-1970s, John Clarke, director of ORNL's Fusion Energy Division since early 1974 and a member of the PLT review committee, urged that neutral-beam injection be applied to the PLT. A decision was made in Washington to assign ORNL the project of building four scaled-up injectors for the Princeton device. Development began here under the direction of Larry Stewart with Hal Haselton as the PLT program manager. By March 1977, when Haselton had replaced Stewart as the leader of the beam section, the first PLT injector was assembled, tested, disassembled, and loaded on two trucks for a trip to Princeton. On the trucks were an ion source, associated electronics, a neutralizer, systems for pumping hydrogen, the ion-removal system, the neutral-beam-transport system, and diagnostic instruments. After the first injector was reassembled, mounted, and put into operation, PLT attained a record high temperature of 25 million degrees.

Over a frantic 15-month period, ORNL built and delivered three more injectors for the PLT and sent engineers and physicists for several days at a time to debug the systems, to solve interfacing problems, and to train Princeton employees to operate the injectors.

The crash program to build the PLT injectors involved the efforts of the Fusion Energy Division, the UCC-ND Engineering Division, and the Y-12 Plant's machine shops. Haselton, Tsai, Stirling, and Stan Ponte provided critical input to the research and development for the PLT injectors and beam lines. Carbide engineers Ed Bryant and Ray Johnson provided the leadership of the UCC-ND Engineering team. Key members of the Y-12 group included R. L. McIlwain (general shop coordination), T. W. Compton (planning, estimating, scheduling), D. Gillespie, Jr. (metal fabrication and welding), W. F. Cartwright (machining), G. Baird, Jr. (dimensional inspection), and J. R. Garrison (mechanical inspection).

DOE's Office of Fusion Energy (OFE) exerted constant pressure on Postma, Clarke, Morgan, and George Jasny (director of the UCC-ND Engineering Division) to expedite assembly of the injectors. Construction and delivery of the systems continued into the fall of 1977 when Morgan became Fusion Energy Division director, replacing Clarke who moved to Washington to work



In this view of the Princeton Large Torus, the cylinders labeled "north," "east," "west," and "south" (the tank, but not the label, can be seen) indicate the location of the neutral-beam injection systems built at Oak Ridge.

...temperatures exceeding 75 million degrees.

for Edwin Kintner as deputy director of DOE's Office of Fusion Energy. (Kintner, OFE director, had written ORNL officials a complimentary letter after the first injector was successfully operated on the PLT.) At the time of Morgan's appointment, ORNL created the Fusion Energy Program and named Berry the director.

Operating at a reduced power level because not all systems were working well, the PLT under the leadership of Harold Eubank achieved the much ballyhooed 60-million-degree temperature in July 1978. With close to full power, the PLT has recently attained temperature levels exceeding 75 million degrees.

At a Washington press conference on August 14, 1978, Melvin Gottlieb, director of the Princeton Plasma Physics Laboratory, called ORNL's development of the injectors "a magnificent source of help to us." Gottlieb told of concerns that the hot hydrogen-deuterium gas mixture in the PLT would clump together in microscopic swirls that would tend to cool the gas and prevent fusions of the deuterium nuclei. "To our great joy," he said, "we found that this is not so."

Buoyed by Princeton's success in raising tokamak temperatures from 25 million to 60 million degrees in a short time, Gottlieb predicted that the 100 million degrees required to fuse nuclei of deuterium and tritium would be achieved in a larger machine such as the TFTR in the 1980s. This Princeton tokamak, which will be heavily shielded to contain the fast neutron radiation from the deuterium-tritium plasma, is designed to prove scientific feasibility—that is, to demonstrate that as much or more energy can be produced than is consumed to ignite deuterium-tritium fusion reactions.

PDX and ISX

Oak Ridge is still in the business of neutral-beam-injection development, but where possible this technology is being transferred to industry. Haselton's group is now building a 1.5-MW injector—with twice the injection power of a PLT injector—for the Poloidal Divertor Experiment (PDX) at Princeton. Princeton has contracted CBI Nuclear Corporation of Ohio to take ORNL designs and build three more 1.5-MW injectors for the PDX. Scheduled to operate with neutral beams in 1980, PDX is designed to test the concept of removing impurities from the plasma by the use of special magnetic-field coils (divertors) to divert the impurities to a collection chamber.

ORNL is also building two 1.5-MW injectors for the ISX, another device for studying impurities. The first Impurity Study Experiment (ISX-A), operated by ORNL and the General Atomic Company from December 1977 until March 1978 and then converted to ISX-B, demonstrated methods for refueling with hydrogen pellets and for keeping impurities out of the tokamak plasma.

ISX-B now has two PLT-class injectors, but these will be replaced with two PDX-class injectors in 1980. The ISX is now being used to study plasmas with a high "beta"—the ratio of plasma pressure to the pressure of the containing magnetic field. The plasma pressure hinges on neutral-beam injection because rapid deposition of energy from neutral beams makes the plasma hot. The hotter the plasma becomes, the more pressure it exerts, the more it tends to expand, and the more it resists confinement by magnetic fields, which exert pressure of their own by physically pushing the plasma in on itself. As the plasma gets hotter, more nuclear fusions occur; consequently more neutrons are produced per unit volume of plasma. In ORMAK, deuterium-deuterium neutrons were produced at a rate of 10^{11}/sec at 20 million degrees. When the ion temperature reached 60 million degrees at the PLT, D-D neutrons were produced at a rate of 10^{13}/sec. The more neutrons produced per plasma volume per second, the greater the power density and overall efficiency of the fusion machine. (In a power-generating

". . . a neutral-beam-power density that will not be surpassed . . . for many years."

fusion reactor, the neutrons will transfer their energy to a lithium-bearing blanket through which a coolant circulates to carry away the heat to the steam-generation system. The neutrons also convert the lithium to tritium, which will be used to fuel the fusion reactors.)

"The efficiency of heating and containing plasmas is strongly dependent on the power density of neutral beams—the amount of neutral beam power compared to plasma volume," says Haselton. "These ISX experiments are important for understanding how to achieve high beta and hence greater efficiency of magnetic confinement. In 1980, when the 1.5-MW injectors are installed on ISX, this relatively small machine will have a neutral-beam-power density that will not be surpassed by other devices for many years."

Neutral-beam injection will increase the plasma pressure and beta, but it will make it more difficult for the magnetic fields from the copper electromagnets to confine the plasma. Says Berry: "Researchers will be using ISX-B to search for the boundary between stability and nonstability in the confinement of the plasma as it is heated to higher temperatures and betas."

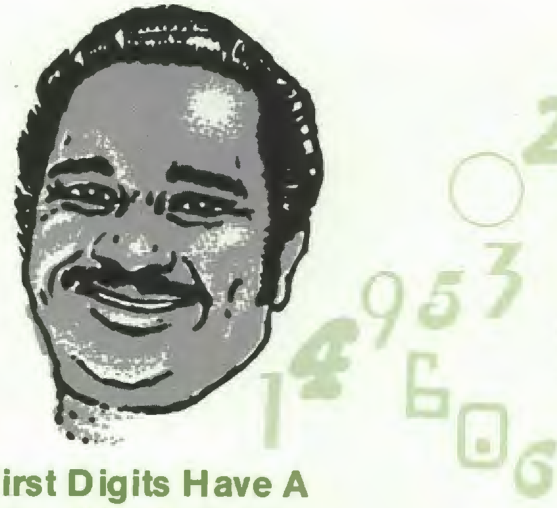
In 1976, John Clarke and Dieter Sigmar predicted that the plasma pressure could be raised by a factor of as much as 10 over what was believed to be the workable limit if one took proper account of the effect of rapid neutral-beam heating. At that time, ORMAK had achieved a beta of less than 1%. Theoretical calculations carried out by Glenn Bateman, Bob Dory, John Hogan, Herb Howe, Dave Nelson, and Martin Peng indicate that ISX-B can reach a beta of 6 to 10% with a circular or D-shaped plasma. If a 5 to 10% or greater beta is achievable, it will mean that smaller, more economical fusion reactors are feasible.

Prospects

Neutral-beam injection is being used all over the world in fusion research machines in the United States, England, France, Germany, Italy, Japan, and Russia. This spring, ORNL is to host an international conference on the application of neutral-beam injection to tokamaks. Speakers will discuss neutral-beam heating on the PLT, the ISX-B, the DITE (Diverted Injection Tokamak Experiment) in England, the TFR in France, and the T-11 in Russia.

Of course, important questions remain for neutral-beam heating, just as there are unknowns concerning the details of building economic fusion devices. Will neutral-beam heating raise plasma temperatures in large tokamaks to the 100 million degrees needed to release enormous amounts of energy? Recent results on the PLT suggest attainment of this temperature is almost certain. Will neutral beam injection work on large, fusing plasmas which are only partially penetrated by the present types of neutral beams? Is there an effective way to protect the injectors from a tokamak plasma's 14-MeV neutrons, which are likely to come back up the beam line and cause secondary electron emission, arc breakdown, and beam ionization? Finally, there is a serious question as to whether such expensive systems as neutral beam injectors will be economical for commercial fusion reactors. Concerning this last question, Morgan says, "The optimum possibility is to use neutral injection to ignite a small plasma in the doughnut which will then be further heated by the alpha particles (helium nuclei produced by fusion reactions). This could result in the neutral injectors being technologically and economically viable."

Despite these unknowns, neutral-beam injection has given physicists cause for believing that fusion is scientifically feasible and that it is now proper to begin examining engineering and economic questions. The technology pioneered at Oak Ridge has also achieved some of the hottest temperatures known on earth. ornl



take a number

BY V. R. R. UPPULURI

Do First Digits Have A Peculiar Distribution?

Suppose we have a large body of physical data, such as the *Farmer's Almanac,* census reports, or the *Handbook of Chemistry and Physics.* One may ask for the frequency of occurrence of the first digit in a body of data such as the molecular weight of thousands of chemical compounds. A priori it seems reasonable to think that each of the nine digits, one through nine, appears equally often in any such data.

In 1938, the physicist Frank Benford observed that this is not so. He investigated several tables of numbers and came up with the wondrously tantalizing conclusion that the nine digits do not appear equally often. He observed that in the first position, the number 1 appears more often than 2, and the number 2 appears more often than 3, and so on. He, in fact, observed that in any table of constants, number 1 appears in the first position 30.6% of the time, and number 2 appears in the first position 17.6% of the time, and so on. More generally, Benford found that the frequency of the digit d being the first digit (in any table of physical constants) was very closely approximated by $\log_{10}(d + 1) - \log_{10}(d)$. This law was referred to as the law of anomalous numbers; and several authors such as R. S. Pinkham and R. A. Raimi tried to give theoretical justification of this phenomenon. Can one rationalize Benford's Law?

A Sorting Problem

Suppose we have n objects, no two of the same weight, which are to be ranked according to their weight. Suppose we only have a balance scale without any measured weights to accomplish this goal. The problem is to find the minimum number of weighings $f(n)$ needed to accomplish this goal.

Clearly, if we have two objects, A and B, this can be accomplished in one weighing. Thus $f(2) = 1$, and we can rank two objects in one weighing. Similarly, if we have three objects, A, B, and C, we can accomplish this goal in $f(3) = 3$ weighings. Suppose the first weighing determines A is heavier than B; then weigh B against C. If B is heavier than C, then the problem is done in two weighings. But if C is heavier, then a third weighing is needed to compare C with A. Similarly four objects, A, B, C and D, can be ranked with no more than $f(4) = 5$ weighings.

The following is a short table of n, the number of objects, versus $f(n)$:

n	1	2	3	4	5	6	7	8	9	10	11
$f(n)$	0	1	3	5	7	10	13	16	19	22	26

A general method of ranking n objects by weight with the minimum number of weighings seems to be unknown.

Karen Cromer, the assistant editor of *Nuclear Division News* at X-10, is on the staff of the UCC-ND Public Relations Department. She has been here since receiving her B.S. in communications in 1976, with a major in public relations from the University of Tennessee. She is shown here, in her office, interviewing Ralph Gable, on leave from the faculty of Davidson College in Davidson, North Carolina, who is faculty advisor this semester for the Southern College University Union students working out their Science Semester at ORNL.

THE OAK RIDGE SCIENCE SEMESTER

By KAREN CROMER

"It's not easy . . . but its worth it," begins a recruiting pamphlet for the Southern College University Union (SCUU) Oak Ridge Science Semester. Established in 1974, SCUU is a consortium of eight southern educational institutions from five states.

Many of the 21 students participating in this winter's program echo the same sentiments: "It's no piece of cake . . . it's a full

At left, Laboratory supervisor Wes Shumate of the Chemical Technology Division and Bruce R. Locke from Vanderbilt University attempt to remove uranium from waste water using bacteria. Locke, a junior majoring in chemical and environmental engineering, is helping develop chemical engineering techniques for upgrading a microbiological process from the laboratory scale to the pilot-plant scale.

At left, SCUU Laboratory supervisor Richard Jones of the Chemistry Division and Denise Y. Williams of Birmingham-Southern College in Alabama, work to develop less expensive surfactants so that oil can be recovered from fields where it is now economically unfeasible. This research project is one of several at ORNL aimed at enhancing oil recovery. Williams is a senior majoring in chemistry.

40-hour-plus work week." "The stakes here are much higher. We're not just trying to pass a test; we're preparing for careers."

This year's students have home bases in 13 states from coast to coast. They represent seven colleges and universities in four states: Alabama, Kentucky, Mississippi, and Tennessee.

Dr. Ralph Gable, faculty advisor for the 1979 SCUU program, explains the science semester concept. "It allows undergraduate students to carry out significant research in an outstanding facility such as ORNL. This is particularly advantageous to students from small liberal arts colleges." Gable, a member of the faculty at Davidson College in North Carolina, is participating in the program by special invitation since Davidson is not a member of the consortium. On assignment with the Chemistry Division's resource and waste chemistry group, he is studying the atmospheric carbon dioxide problem.

Gable came to Oak Ridge in December with his wife, Wendell. Setting up residence in a furnished apartment, he proceeded to familiarize himself with the Laboratory and the community. One of his functions as faculty advisor was to serve not only as a liaison between SCUU and ORNL but also as an information resource for the students concerning such matters as housing, banking, utility connection, telephone installation, shopping, and dining and recreational opportunities.

"When the students arrived in Oak Ridge in early January, they were given an orientation to the Laboratory and the community," said Yvonne Lovely, who administers the program for ORNL's Office of University Relations and Professional Edu-

Paul J. Caldwell, Southwestern at Memphis, is attempting to make a self-supporting diffraction gradient, which is faster and less expensive to develop. He does this holographically by crossing two laser beams and recording the interference pattern. On assignment with the Physics Division, the senior physics major is working with Ed T. Arakawa.

cation. The four-month program provides juniors and seniors with opportunities for research and study in the following areas: engineering, physics, chemistry, biology, ecology, metallurgy, mathematics, and economics.

"A similar program—one which was the forerunner of the SCUU program—has been conducted each fall at the Laboratory since 1970," said Lovely. "The Fall Science Semester is for participants in the Great Lakes Colleges Association–Associated Colleges of the Midwest, a consortium of 25 colleges and universities. The science semesters are cosponsored by the participating consortia and the Department of Energy."

Under the guidance of ORNL staff members, SCUU participants carry out research in areas of each student's major field of interest. The research areas range from projects aimed at enhancing oil recovery to those dealing with DNA and carcinogens. A look at a cross section of SCUU student research projects illustrates how the backgrounds of the participants are matched with the division assignments.

Bruce R. Locke, a junior at Vanderbilt University working

Barbara A. Broughton, Centre College (Kentucky), has been assigned to the Biology Division, where she is observing the effects of certain coal-conversion by-products on the growth, respiration, behavior, and development of Tetrahymena pyriformis, *a ciliated protozoa. The senior biology major is working under the direction of James Dumont.*

Jan M. Coe, Centre College, is testing deciduous trees during the winter months to evaluate their photosynthetic capacity and changes during the dormant period. The senior biology and environmental science major works with Sandy McLaughlin, terrestrial ecology section, Environmental Sciences Division.

Patti L. Holt, a junior biology and art major, has been assigned to the Biology Division under the guidance of her Laboratory supervisor, Howard Adler, leader of the microbial genetics group. The Centre College student is investigating the mechanism of cell division using Escherichia coli.

on a double major in chemical and environmental engineering, appears to be well placed. Under the direction of Wilson Pitt in the Chemical Technology Division, Locke is developing some of the chemical engineering techniques for upgrading a microbiological process from laboratory to pilot-plant scale. The specific process deals with the removal of uranium from waste water using bacteria.

A senior chemistry major at Birmingham-Southern College (Alabama), Denise Y. Williams has been assigned to the Chemistry Division, where Josh Johnson is her Laboratory supervisor. Her research project is one of several at ORNL aimed at enhancing oil recovery.

"It is known that the addition of surfactants to oil wells can significantly increase oil recovery," said Williams. "For this purpose, detergents have to be used in large quantities, and cheaper detergents would make it economically feasible to recover oil from many fields where it is now too expensive. Therefore, my project involves working with others to develop surfactants which cost less. Specifically, we are trying to make fatty-acid carboxylates (widely available natural products) more effective as surfactants by modifying their structure."

A junior in economics and management at Centre College in Kentucky, Karen Frisina is working with Ken Corum of the Energy Division, where she puts her textbook knowledge into real-world application. "My final product will involve a regional microeconomic analysis of solar-heating versus conventional space-heating systems."

Ed Maggart, a biology major from the University of the South at Sewanee, has been working with Barbara Walton, an entomologist in the Environmental Sciences Division. He is investigating the effects of acridine, one of the chemical by-products of coal conversion, on crickets. By using low levels of acridine, which are both sublethal and environmentally realistic, he

Mark L. Friedman, a junior biochemistry major, is working with Mayo Uziel in the Biology Division, where he is isolating transfer RNAs from normal and malignant tissue cells and detecting any structural changes in the nucleotides of the tRNA. He attends Centre College.

is determining whether these levels of the chemical in food influence reproduction and growth. His goal is to determine how this chemical affects insect populations and other invertebrates.

Considering the time it takes to train and advise the SCUU students, do the Laboratory supervisors working on a one-to-one basis with them think the four-month investment is a worthwhile venture? Two Laboratory advisors shared their comments.

"Absolutely!" declared Lawton Smith of the Biology Division, who has served three years as his division's university relations coordinator, with responsibility for assigning students to different biology researchers. "Both the student and the researcher profit from this arrangement. The findings of many students are often significant contributions to publications."

He emphasizes that the students are not given "busy work." "I don't know of any supervisor who has used his or her student as just another pair of hands."

Smith speaks from experience. Having worked both as university relations coordinator and as a laboratory supervisor, he has seen 30 students pass through his division, either as SCUU participants or as participants in similar programs.

Barbara Walton, who is serving as advisor to Ed Maggart, assigned to the Environmental Sciences Division, also feels the investment is worthwhile: "Even though this is my first experience with the SCUU program, I see rewards in two areas. First, I find answers to problems I don't have time to research myself. Second, with respect to the projects assigned to Ed, I'm not under pressure to reap immediate results from these projects. His findings may be exploratory in nature, suggesting new ideas for research."

In addition to work on their research assignments, students attend a three-day training course at Oak Ridge Associated Universities. This consists of lectures and laboratory sessions dealing with applications of radioactive isotopes. They also participate each week in an interdisciplinary colloquium. About half the students are taking a history of science course taught by Gable, while others are pursuing independent studies under home faculty or are taking courses through the University of Tennessee.

The students receive not only hands-on experience but also academic credit. The Oak Ridge Science Semester—including research participation, one resident course (or independent study course), and the seminar series—is considered equal to one full term's work, or a maximum of 16 semester hours. Occasionally, students who make special arrangements to extend

Verba A. Moore, Millsaps College in Mississippi, is working with transfer RNA trying to establish a pathway in the production of a protein which is not always present in a normal cell. The protein is used for detoxifying metals. A premedicine senior majoring in chemistry, she works with Lee Shugart in the Biology Division.

Michael C. Cronen, a junior majoring in chemistry, has been assigned to the Biology Division's cancer and toxicology section. Under the guidance of Arend Kootstra, he is working with DNA and carcinogens, specifically, the binding of benzo[a]pyrene diol-epoxide to the histone proteins. Cronen attends Centre College.

their research terms may be granted more credit than the normal maximum.

"Selection of participants is made by the SCUU Science Policy Committee (composed of faculty in the eight-college consortium), with the advice and assistance of Laboratory scientists," said Lovely. "Final selection is based not only on grades, which are an important factor, but also on whether the students' background experience fits the scientists' current research needs." Usually, applicants should have at least a 3.0 overall grade-point average and no lower than a 3.0 average in their major field, based on a 4.0 scale.

Most students participating in the program are juniors or seniors majoring in biology, chemistry, physics, engineering, mathematics, and economics. Students majoring in other scientific and social science disciplines may also be eligible.

Participating institutions in the Southern College University Union include: Birmingham-Southern College, Alabama; Centenary College, Shreveport, Louisiana; Centre College, Canville, Kentucky; Fisk University and Vanderbilt University, Nashville; Millsaps College, Jackson, Mississippi; Southwestern at Memphis; and the University of the South, Sewanee, Tennessee.

The 21 SCUU students currently at the Laboratory by division and educational institution are as follows:

Biology: Barbara A. Broughton, Michael C. Cronen, Mark L. Friedman, and Patti L. Holt, all of Centre College; Verba A. Moore and Duane B. Shroyer, Millsaps College; and Ronald C. Watson, Birmingham-Southern College.

Chemical Technology: Bruce R. Locke, Vanderbilt University.

Chemistry: Charles M. Fowler and Mark L. Mudano, University of the South; Timothy A. Whitley, Southwestern at Memphis; and Denise Y. Williams, Birmingham-Southern College.

Energy: Karen Frisina, Centre College; and Kathleen H. Herbert, University of the South.

Environmental Sciences: Jan M. Coe, Centre College; Catherine C. Keffer, Ed F. Maggart, and Mel S. Schulze, University of the South; and Karla F. Vetter, Eastern Kentucky University, which is participating in the SCUU program through special permission.

Health and Safety Research: Paul J. Caldwell, Southwestern at Memphis.

Oak Ridge Associated Universities: Robert W. Butler, Centre College.

awards and appointments

Carol A. Heckman has been appointed to a second term on the National Science Foundation's Advisory Committee on Cell Biology.

Ted Lundy has been named manager of the National Thermal Insulation Materials and Systems Programs for the Department of Energy.

R. A. Bradley has been appointed manager of the National Fossil Energy Materials Program for the Department of Energy.

In the joint competition held recently by the East Tennessee chapters of the Society for Technical Communication and Industrial Graphics International, the following ORNL entries received awards: *Energy Division Annual Progress Report* by **Bill Fulkerson,** first prize, annual reports category; *Chemical Technology Division Annual Progress Report* by **Don Ferguson** and staff, second prize, annual reports category; *Neutron Physics Division Progress Report* by **Lorraine S. Abbott,** second prize, annual reports category; *Proceedings of the 1977 DOE Statistical Symposium* by **Donald A. Gardiner** and **Tykey Truett,** third prize, books category; *Teaching Your Heart to Survive,* first prize, brochures category; *United States Uranium Enrichment Services* by **Joe W. Gollehon,** second prize, brochures category; *President Carter's Visit to Oak Ridge National Laboratory, May 22, 1978,* second prize, brochures category; *Bibliography of Reports on Research* by **Joel Buchanan,** first prize, compilations category; *Geological and Geochemical Aspects of Uranium Deposits: A Selected Annotated Bibliography, Vol. 1,* by **M. B. White** and **P. A. Garland,** second prize, compilations category; *HTGR Safety: Review of Current Issues and Bibliography* by **Joel Buchanan** and **G. W. Keilholtz,** third prize, compilations category; *Reactor Operating Experiences, 1975–77* by **G. T. Mays** and **R. L. Scott,** fourth prize, compilations category; *Environmental Monitoring Handbook for Coal Conversion Facilities* by **M. S. Salk, S. G. DeCicco,** and Radian Corporation, second prize, handbooks category; *Regional Transportation Energy Conversion Data Book* (first edition), fourth prize, handbooks category; *ORNL Review,* **Barbara Lyon** and **Carolyn Krause,** first prize, house organs category; *Nuclear Safety,* edited by **William B. Cottrell,** first prize, journals category; *Synthetic Fuels Process Research Digest,* edited by **Fred O'Hara,** second prize, journals category; "Large Thermocouple Thermometry Errors Caused by Magnetic Fields," *Review of Scientific Instruments,* by **T. G. Kollie, R. L. Anderson, J. L. Horton,** and **M. J. Roberts,** first prize, journal research articles; "Uranium Assay of Phosphate Fertilizers and Other Phosphate Materials," *Health Physics,* by **Edward J. Bouwer, John W. McKlveen,** and **W. J. McDowell,** fourth prize, journal research articles; "The Ecological Society of America Historical Data and Some Preliminary Analyses," *History of American Ecology,* by **Robert L. Burgess,** first prize, journal review articles; "Fuel from Accelerators—An Alternative to Breeder Reactors?" *ORNL Review,* by **Lorraine S. Abbott,** first prize, news articles category; *ORNL Regional Energy Newsletter,* edited by **Betty Galyan Shields,** second prize, newsletters category; *The Role of Electron Accelerators in U.S. Medium Energy Nuclear Science,* **R. S. Livingston,** Study Group Chairman (**L. Foster** and **J. Swift,** editors), first prize, technical reports category; *Reviews of the Environmental Effects of Pollutants. IV. Cadmium* by **A. S. Hammons, J. E. Huff, H. M. Braunstein, J. S. Drury, C. R. Chriner, E. B. Lewis, B. L. Whitfield,** and **L. E. Towill** (authors) and **Carol B. McGlothin** and **Anita B. Gill** (editors), second prize, technical reports; and *Radiological Impact of Airborne Effluents of Coal-Fired and Nuclear Power Plants* by **J. P. McBride, R. E. Moore, J. P. Witherspoon,** and **R. E. Blanco,** third prize, technical reports.

In the technical art categories, ORNL winners were **John Waggoner,** third prize in brochure design and third prize in cover design, and **David Cottrell,** third prize in visual aids/charts.

Richard F. Kimball has been designated a Corporate Research Fellow by the Union Carbide Corporation's Nuclear Division.

Paul Blakely has been appointed chairman of Meeting Publications for the newly established Publications Steering Committee in the American Nuclear Society.

Robert J. Gray and **Gerald M. Slaughter** have received "Certificates of Appreciation" from DOE for their participation in the investigation of the September 21, 1978, explosion and fire at the Strategic Petroleum Reserve in West Hackberry, Louisiana.

Stanley I. Auerbach is a juror for the 13th annual Chief of Engineers Design and Environmental Awards Program.

Noah R. Johnson has been elected a Fellow of the American Physical Society.

David E. Reichle has been appointed to a two-year term on the National Science Foundation's Advisory Subcommittee for the Applied Physical, Mathematical, and Biological Section of the Division of Applied Research.

LaRue Foster was elected vice-president of the East Tennessee Chapter of the International Association of Business Communicators.

William R. Busing has been appointed a member of the Committee for Crystallography of the National Research Council.

Sheldon Datz has been named a Corporate Research Fellow by the Nuclear Division of Union Carbide Corporation.

Gerald M. Slaughter has been selected to present the Comfort A. Adams Lecture at the American Welding Society's annual meeting.

James D. Regan has been selected as a Fellow of the Japan Society for the Promotion of Science.

Stanley I. Auerbach has been named an editor of *Environment International,* a new journal of science, technology, health, monitoring and policy.

Charles C. Coutant has been appointed to a three-year term on the advisory board of *Environmental Science and Technology.*

M. S. Salk and **Steve DiCicco,** with Radian Corporation and the ***ORNL Technical Publications Department,*** won the Award of Excellence (second place) in the Handbooks category, for "Environmental Monitoring Handbook for Coal Conversion Facilities," in the International Technical Communications Conference competition. The award will be presented at the conference's 26th annual meeting in Los Angeles this month.

W. Harvey Gray has been asked to serve on the Computer Technology Committee of the ASME Pressure Vessel and Piping Division. He has also been asked to serve on the Review Board for the Journal of Applied Mechanics.

Yok Chen was appointed Fellow in the American Physical Society.

Ed Kobisk has been elected to the Board of Directors of the International Target Development Society.

Liane Russell has been inducted into the Hunter College Hall of Fame in recognition of her contributions to the field of radiation mutagenesis.

In the month of February of this year, a card was mailed to everyone on the "internal" distribution list (employees only) for the ORNL Review. *The card contained instructions to the effect that the recipient who wished to continue to receive the publication should return the card in the plant mail. The response indicated that 81% of the salaried employees and 17% of the hourly employees want to continue to receive the* Review. *However, identifying the employees who did not return the card will be such a large job that for many of them, the first issue to be missed will be the Summer 1979 issue, rather than this one, as was promised on the card. As of this writing, similar cards are in preparation for the external mailing list.*

OAK RIDGE NATIONAL LABORATORY *REVIEW*
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This stitchery, commissioned by Herman Postma of Sharon Fields to represent the variety of people who work at ORNL, now hangs on the Laboratory Director's office wall. It is worked in mixed fibers, in tones of brown and green and coral with a natural fiber background. Fields is employed by the Anderson County Community Action Commission as a craft center developer in charge of the Community Craft Cooperative, near Norris. She is the wife of David Fields, a member of the Computer Sciences Division. The panel is over three feet long.