Number Two 1984

Oak Ridge National Laboratory review

Large Scale, Small Scale

State of the Laboratory-1983

THE COVER: The heavy-ion accelerator at the Holifield Heavy Ion Research Facility is a good example of Large Scale, Small Scale, the theme of Herman Postma's 1983 "State of the Laboratory" address. This huge machine, which dwarfs the workers below, is used to study the nuclear physics of the smallest-scale phenomena. In 1983 the highest beam energy obtained at this facility was achieved with the acceleration of bromine ions to 1 billion electron volts. This is one of many achievements presented in Postma's address, beginning on page 1.

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DEPARTMENTS

OAK RIDGE NATIONAL LABORATORY
operated by Martin Marietta Energy Systems, Inc.
for the Department of Energy

ORNL director Herman Postma (left) chats with Ken Jarmolow, president of Martin Marietta Energy Systems, Inc. Looking on are Larry Adams, president of Martin Marietta Corporation, and Mary Jane La Barge, corporate secretary.

State of the Laboratory-1983

Large Scale, Small Scale

By HERMAN POSTMA

Often in the past, it has been tempting to use the theme "Year of Transition" to describe the impact of changing national energy policies or research and development (R&D) philosophies on the activities of Oak Ridge National Laboratory. But now, as I present this annual review of the Laboratory's important accomplishments and goals for the tenth time, that familiar phrase is fact. On April 1, 1984, we completed what a year ago may have appeared an enormous, time-consuming, even ominous task—the selection of and change to a new operating contractor for ORNL and the other U.S. Department of Energy facilities.

With the perspective of hindsight, we can see that many individual and institutional concerns about the process of change and its possible effects were exaggerated. In fact, the entire sequence has proceeded on schedule with minimal impact on people and programs, thanks to the excellent work of DOE and its local and headquarters staffs. Their performance under difficult and demanding circumstances was extraordinary. As a result, we have benefited from a very stable and orderly transition, which has permitted continuity in programs and caused no hardship on employees.

With the formal transition process begun in January now complete, it is truly a pleasure for me to welcome, on behalf of the Laboratory, all of our friends and colleagues from Martin Marietta Energy Systems, Inc. We congratulate them on a successful proposal—and wish for them in this new venture a good beginning and continuing success.

While the theme of my State of the Laboratory address will not be transition per se, I do want to comment specifically, now and later, on this central concern for all of us during this year of the contractor selection and change. However, as usual, I will emphasize R&D accomplishments throughout the Laboratory. The first achievements selected will illustrate the multiple dimensions of "scale" in our work—from subatomic to global phenomena, from individual investigation to large team efforts, from small component development

ORNL staff members chat at the reception following the State of the Laboratory address at the Museum of Science and Energy in Oak Ridge.

to large engineered systems, and from isolated contributions to sustained long-term endeavors. Thus my theme is Large Scale, Small Scale, which, after a few introductory comments, I will illustrate with examples and discussion (starting on page 4). I will also discuss a series of important project and program milestones achieved in 1983 (see page 26). Finally, I will focus on the outlook for the year ahead, including expected occurrences under Martin Marietta Energy Systems and our short- and long-term needs and objectives in an area of continuing importance and public attention—namely, environmental management.

As always, I can touch on only a small fraction of the year's many worthy and outstanding technical achievements. With this limitation in mind, another portion of the address (beginning on page 14) will be what I hope is a representative, if not comprehensive, sampling of highlights from all areas of our program activity, including both sciences and technologies.

High Visibility

Certainly, viewed overall, 1983 was a year of high visibility for the Laboratory in many areas beyond its R&D missions. Examples include the efforts to attract high-technology companies to the Tennessee Technology Corridor, cooperative activities with our institutional neighbors, environmental matters of both local and national concern, and, of course, widespread interest and involvement in the selection of a new operating contractor. Nationally, 1983 was the "year after" multiple high-level inquiries and reports on the status and function of DOE laboratories and federal laboratories in general. Although the reports differed in tone and focus, they agreed that national laboratories (1) have been hampered by overmanagement by federal sponsors, (2) need more flexibility in administering R&D funds, (3) require clearer statements of institutional missions, and (4) should undergo more rigorous independent review. Already within DOE we see evidence of a concerted effort toward improvements in each area, such as reducing unnecessary or duplicative reporting, approving increased discretionary funds for purely exploratory research, and including the independent review process in the Request for Proposal issued to prospective replacement contractors.

The public focus on environmental management issues, beginning with the past losses of mercury from the Y-12 Plant, has continued as Congress, DOE, and other involved state and federal agencies have reviewed all facets of the environmental and health impacts of the Oak Ridge Operations, including ORNL. In cooperation with the Tennessee Department of Health and Environment and regional Environmental Protection Agency (EPA) officials, ORNL participated in a compliance evaluation inspection of its current National Pollution Discharge Elimination System permit, which is now up for renewal. These state and federal reviews have included on-site inspection and detailed documentation of all facets of our monitoring, processing, and disposal of gaseous, liquid, and solid radioactive and hazardous wastes.

This year also has been notable for a potentially significant change in DOE consulting and patent policies that will affect the Laboratory. By liberalizing consulting provisions and by permitting the contractor organization to receive a patent waiver for marketing and licensing developments resulting from DOE-sponsored R&D, DOE has boosted our efforts to achieve stronger and more productive laboratory-industry interactions and to accelerate the rate of technology transfer.

Finally, in 1983 ORNL entered into a host of new cooperative initiatives that represent important directions for us. Among them are the Research Institutions Consortium, which formally links the mutual interests of ORNL and our academic and governmental neighbors; the University of Tennessee-ORNL Distinguished Scientist Program, under which initial appointments were made in 1984; two major new facility approvals, including the much-anticipated High-Temperature Materials Laboratory and an innovative fusion experimental device, the Advanced Toroidal Facility; joint fusion endeavors with both Atlanta University and the Japan Atomic Energy Research Institute; and a materials-science partnership with the Cabot Corporation (in which Cabot will fund R&D by our metallurgists and send a researcher to ORNL to work in the area of long-range-ordered alloys).

A Matter of Scale

Last year my State of the Laboratory address focused on Long-Range, High-Risk, High-Payoff R&D as the Laboratory's primary and continuing mission. Fulfilling that role and related objectives may involve developing and operating unique national resources such as our various user facilities (my 1982 theme); mobilizing diverse technical resources and institutions to carry out large, complex, interdisciplinary tasks; or performing high-quality R&D that spans a continuum from Big Science to Little Science. That natural interaction of scale and complexity, involving both the objects of study or development and the tools applied to the task, is the basis for my choice this year of the Large Scale, Small Scale theme.

This crucial and characteristic dimension of a national laboratory's purpose and programs is very evident throughout ORNL. R&D may involve big instruments and large numbers of users to study the smallest-scale phenomena, as in nuclear physics research. In the area of regional, national, or global environmental concerns, the challenge is to make coordinated measurements on the same broad scale to define and ultimately to solve the problems. Cooperative national or international R&D endeavors, mobilizing large-scale resources for a task beyond the means or capability of any one participant, constitute another example.

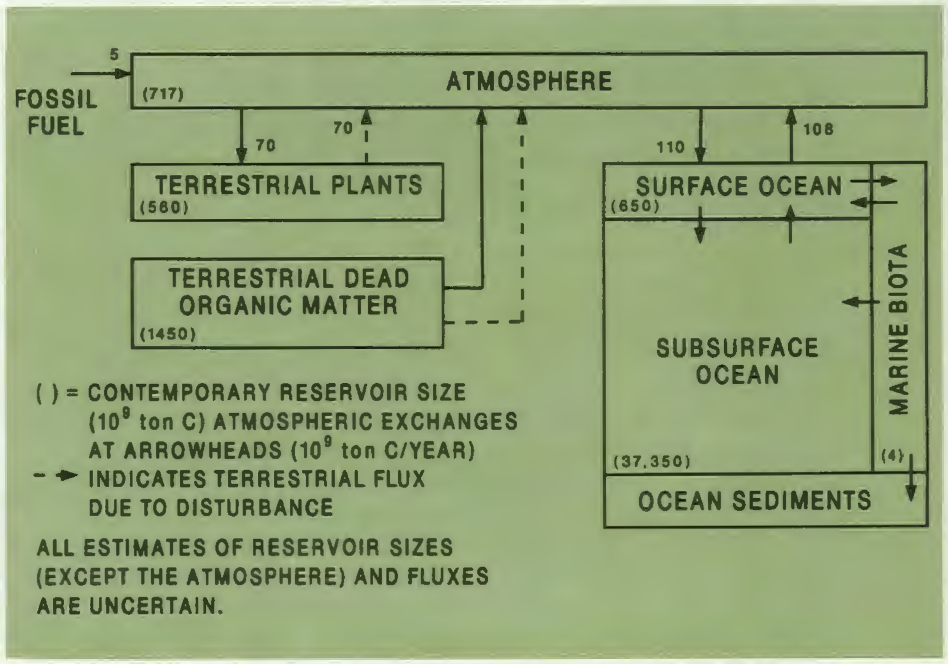
Interactions of scale, from very small to very large, also can be seen in the physical or biological alteration of a material or property at the microlevel, resulting in macro effects on overall performance or function—and ultimately in even greater impact on society or commerce. The synthesis of diverse data from multiple sources, building an integrated and useful output from highly variable and inconsistent inputs, may be seen as the macro-to-micro reverse of that process. Design and construction of a large engineered system, incorporating a multitude of individual component developments, also reflect the same continuum of scale and effort. Finally, time itself is an example of the large impact of accumulated small efforts, as in the continuity of a major long-term project or the institutional "memory" that allows experience of the past to influence decisions of the present.

In developing this theme of Large Scale, Small Scale, I have selected examples from both the science and the technology areas to illustrate one or more of the thematic characteristics. These achievements are presented in the following capsules. My remarks on program milestones and the outlook for the year ahead appear on page 26.

Global Environmental Concerns: ORNL Studies Carbon Dioxide and Climate

There is perhaps no more dramatic example of large scale, both in the phenomena involved and in their potential consequences, than two areas of global environmental concern—the postulated climatic warming, or "greenhouse effect," caused by increasing levels of atmospheric carbon dioxide (CO_2), and the environmental effects of acidic deposition, including acid rain. The problems themselves are truly global, and their solutions will require understanding of complex physical, chemical, and biological processes on the same scale. The scientific attack must involve global monitoring, measurement, and modeling, using the largest and fastest computer tools available. ORNL, through the Environmental Sciences Division (ESD), has key national and international roles in each endeavor.

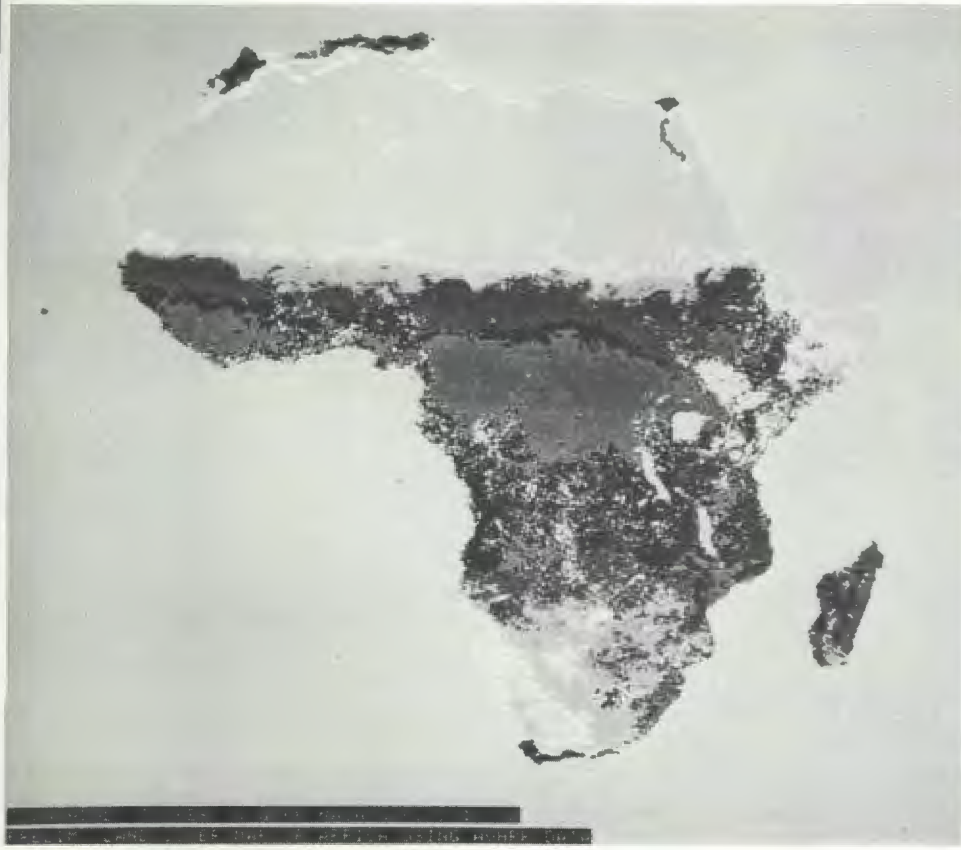
In investigating the global carbon cycle, ESD has three functions. First, it provides scientific leadership in formulating global carbon simulation models and performing sensitivity and uncertainty analyses of key model parameters. Second, it is responsible for managing DOE's entire research effort on modeling and much of the supporting field research. This effort involves subcontracting and managing projects at ten universities and other federal laboratories, as well as coordinating contributions from three other ORNL divisions—Chemistry, Computer Sciences, and Health and Safety Research—and other collaborators at the Oak Ridge Associated Universities. Third, ESD is charged with assessing, by 1985, the state of knowledge about the global carbon cycle. This assessment will identify the research needed to more accurately predict future atmospheric CO_2 concentrations. The assessment also will guide DOE in establishing future directions for research on the environmental effects of climate changes due to CO_2 levels.



This schematic shows the exchange between the ocean and the atmosphere and between vegetation and the atmosphere of carbon dioxide, which is emitted by the combustion of fossil fuels. The aim of ORNL's carbon inventory is to resolve the uncertainties associated with the exchange of carbon among the principal reservoirs.

This past fall, through its sixth Life Sciences Symposium, ORNL hosted some 300 members of the international scientific community involved in research on the global carbon cycle. Those scientists reported analyses of the natural cycle and implications of human alterations for the next century. Another local resource for global carbon cycle research is the Carbon Dioxide Information Center, which compiles and disseminates the worldwide scientific literature. Operated by the Information Division, this center maintains a computerized data base that contains more than 6000 citations.

The goal of these ORNL-led efforts is to determine how much CO_2 is annually injected into the atmosphere. From an ecological and geochemical perspective, it is necessary to understand how much released carbon is absorbed by "sinks" such as the oceans and how much additional carbon potentially enters the atmosphere from "sources" such as the clearing of forests. Since 1958, measurements taken at Mauna Loa Observatory in Hawaii have shown a steadily increasing concentration of atmospheric CO_2. That increase, however, represents only about half of the carbon produced annually by human activities such as fossil fuel burning and forest clearing. The remainder is being removed and stored in the oceans and, perhaps, in part of the earth's vegetation. The objective, then, is to determine the biological, chemical, and physical nature of the absorption processes on a global scale, as well as factors that may limit or increase the ultimate capacity of the oceans and vegetation to store carbon.



This satellite image of Africa shows the location of major vegetation types, denoted by varying color distributions. The northern half of the continent is mostly desert, and the southern half is largely forest. There is evidence of forest clearing, which is a source of carbon dioxide. ORNL has recently produced a high-resolution global map of major vegetation types ranked by their carbon storage capacity.

This year Jerry Olson and Julia Watts of ESD have produced the first high-resolution global map of major vegetation types ranked by their carbon storage capacity. This map serves as a baseline to determine the effects of future forest clearing, reforestation, agricultural expansion, and desertification on the terrestrial absorption of CO_2. Large-scale mathematical simulations are being developed to predict the effects of a warmer climate on major agricultural and forested regions and on the ability of sinks to retain carbon.

Robert Gardner and John Trabalka have applied sensitivity and uncertainty analyses to understand why the results predicted by global carbon-cycle simulation models deviate from the Mauna Loa numbers on increasing atmospheric CO_2 levels. They found that the deviations are most sensitive to model inputs associated with the forest-clearing record, the average depth distribution of carbon-14 in the ocean, the preindustrial concentration of CO_2 in the atmosphere, and the temperature response of ocean surface waters to CO_2-induced climate change. The first input represents the principal data that must be examined in attempting to resolve the role of the terrestrial biosphere in absorbing and releasing carbon. The last input is important because it represents one facet of a potential climate feedback on the carbon cycle—namely, the ocean's highly temperature-sensitive chemical equilibria, which partially control the magnitude of the exchange of carbon between the ocean and the atmosphere.

Gardner and Trabalka have found that making accurate predictions about future climatic change and its environmental impacts is particularly difficult because fossil-fuel emissions are dependent on many unknowns. These uncertainties arise from the difficulty of projecting the demand for fossil-fuel energy in light of questions about the world's economy and the future role of nuclear power. Gardner and Trabalka's analysis also emphasizes the need to collect data to improve our understanding of the role of the terrestrial biosphere as a carbon source and sink, air-sea exchange and ocean transport of carbon, preindustrial levels of atmospheric CO_2, and the atmospheric behavior of CO_2. Ultimately, this analysis shows that assumptions about land-use practices and fossil-fuel use plus differences in model structure are more likely to affect the accuracy of predictions than are uncertainties in current models associated with individual parameters such as preindustrial CO_2 concentrations.

How Pollution and Acid Rain Affect Vegetation Is Studied

ORNL is also strongly involved in research on another global environmental concern—the deposition of acids on soil, vegetation, and lakes and streams by rain, snow, and the fallout of dry particles. These acids are formed in the atmosphere by the interaction of moisture with sulfur dioxide and nitrogen oxides emitted by the combustion of fossil fuels and natural sources such as volcanoes.

ESD staff members are involved in large-scale projects in three areas to improve scientific understanding of the potential magnitude and mechanisms of the environmental effects of acidic deposition. With funding from the Electric Power Research Institute, ESD is studying acidic deposition's effect on the cycling of forest nutrients and also on the productivity of agricultural crops. New work is beginning this year on the ecological effects of acidification on streams. EPA has chosen ESD to

Large Scale, Small Scale

ORNL soil scientist Dale Johnson inserts a plate lysimeter between surface soil layers to extract water for chemical analysis. Analysis of these solutions provides measures of nutrients removed from forest soils by acidic solutions such as acid rain.

Open-topped exposure chambers like these use activated charcoal filters to exclude ambient gaseous air pollutants such as ozone from field-grown crops. ORNL has combined this system with movable covers that can exclude ambient rainfall. The unique combination of these exclusion techniques permits scientists to evaluate the potential for either of these forms of plant stress (ozone or acid rain) to influence the plant's response to the other.

coordinate a 12-institution regional study of the long-term effects of acidic deposition on forest growth in the eastern United States. ORNL also continues to play a lead role in the National Laboratory Consortium, which supports the Interagency Task Force on Acidic Deposition's definition of national scientific priorities.

Forest-nutrient-cycling research on Walker Branch Watershed, performed by ESD's Dale Johnson and Dan Richter, shows that acid deposition has approximately doubled the natural rate of leaching of cations from the soil. Cations include positively charged ions of nutrient elements that are attracted to negatively charged soil particles. These cations can be leached, or pulled away from the soil particles, by negatively charged sulfate ions introduced to the soil by acidic deposition. This increase in the removal of cations, however, represents only a small fraction of the total reserves of nutrients and is not seen as a threat to the ecosystem.

Interestingly, even though leaching rates have doubled, not all cations are being lost. For example, calcium-poor sites, which are common on the watershed, do not lose calcium, because atmospheric inputs of calcium apparently equal leaching outputs. Rather, these sites lose sodium, magnesium, and potassium. This conservation of calcium is important for forest nutrition because calcium is a potentially limiting element—that is, it is in such low supply in the soil that further losses might limit forest growth. These results, as well as theoretical considerations, suggest that limiting cations will be conserved while nonlimiting cations (nutrients in plentiful supply) will be partially lost through the accelerated leaching caused by acid deposition.

Over the past 18 months, ESD's Samuel B. (Sandy) McLaughlin has been charged with planning, coordinating, and analyzing results of a

ORNL coordinates studies by research stations in 15 states on the impacts of acid rain and ozone on forest growth.

large-scale, regional study of the effect of air pollution on forest growth. The study's purpose is to quantify long-term changes in forest growth and determine whether these changes are related to stresses caused by gaseous pollutants (primarily ozone) and acid rainfall. The broadly collaborative project involves 12 research centers, including university, state, and federal laboratories, all of which use a common research plan.

Samples have been taken from approximately 6000 trees representing 34 species and 88 forest stands distributed over 15 eastern states. Both potentially acid-sensitive and acid-resistant sites are included. Early results from the sample analysis indicate that a systematic decline in tree growth began about 25 years ago in many areas of the eastern United States. This decline has affected primarily pine, fir, and spruce, including high-elevation forests in the Great Smoky Mountains National Park.

In the area of crop productivity, Dave Shriner and Bill Johnston have designed studies to measure the combined effect of ozone and acid rain on winter wheat and soybeans. Preliminary results from the first year of this large three-year field experiment indicate the possibility of "nonadditive" interactions between acid rain and ozone; that is, the exposure of wheat to both ozone and acid rain may inhibit crop growth more than if the wheat were exposed to acid rain alone.

These preliminary observations are significant because they suggest that (1) wheat is relatively tolerant of acid rain even at "worst case" exposure levels, which are ten times more acidic than current ambient levels, and (2) the potential interactive effects of acid rain and ozone might make the adverse impacts of ozone on crops more severe than currently thought. The results also suggest that for some species of vegetation, response to acidic precipitation may be dependent on the plant's response to air pollutants such as ozone. The nature and direction of that interaction are being actively explored.

Improving Materials by Changing their Surfaces: A Better Surgical Hip Joint

The dimension of scale also is evident in our work on surface modification of materials—modifications that involve only a few atomic layers at the surface yet have dramatic effects on the overall characteristics and performance of a material. For example, by using accelerators to introduce ions into a material's near-surface region, we have produced materials with harder surfaces, greater resistance to wear and corrosion, and improved electrical properties. That micro-macro contrast is extended further when one considers the much more wide-ranging technological and commercial impact of the altered materials, which already are leading to new products and new device applications.

The Surface Modification and Characterization Facility in the Solid State Division combines ion implantation and pulsed-laser processing for modifications of the near-surface regions of materials with in situ ion-beam analysis and surface characterization in ultrahigh-vacuum environments. The equipment available includes energetic ion accelerators and high-powered lasers. A Collaborative Research Center was established this year to make the facility's capabilities more widely available to university and industry scientists; there are now approximately 40 projects ranging from fundamental materials research to proof-of-principle experiments for possible commercial applications. Staff time is devoted two-thirds to basic research sponsored by the DOE Division of Materials Sciences and one-third to collaborative projects with outside investigators. Bill R. Appleton directs the Collaborative Research Center, and he and C. W. (Woody) White are coleaders of the Surface Modification and Characterization Facility.

Because ion implantation, ion-beam mixing, and laser annealing are nonequilibrium processing methods (unlike alloying), they can be used to produce new and often unique material properties that are not possible with conventional fabrication techniques based on equilibrium processes. This ability makes ion-beam and laser processing ideal tools for fundamental materials research. They are equally useful for modifying surface properties for practical applications such as reducing friction, increasing resistance to wear and corrosion, speeding up chemical reactions via catalysis, and increasing surface hardness. ORNL's most visible efforts have been the use of these techniques to improve the electrical properties of solar cells, to fabricate new semiconducting alloys, and to increase the resistance to corrosive wear of surgical implant alloys. (continued on next page)

Recently at ORNL, samples of the titanium-aluminum-vanadium (Ti-6, Al-4, V) alloy used in artificial hip joints were subjected to a 10-h corrosive-wear test in saline electrolyte. The samples that were implanted at ORNL with nitrogen ions (like the one at top right) showed very little corrosive wear, unlike the unimplanted sample (top left). Below is an artificial hip joint, composed of a stem and ball made of the titanium alloy, which is inserted into a polyethylene cup.

Bill Appleton (left), Wayne Holland, Woody White, and Jagdish Narayan gather at the ion implantation accelerator, where they developed a new class of supersaturated substitutional alloys of silicon. The four researchers received an I•R 100 award in 1983 for these alloys, which can be used for high-power transistors, diodes, and advanced integrated circuit devices.

Our effort to improve the performance and useful life of a surgical implant alloy illustrates the range and potential widespread impact of the ion-implantation technique for surface modification. Each year more than 75,000 Americans receive artificial hip joints, in which a metal-alloy "ball" moves within a polyethylene "socket" to provide the same movement of the thigh as a natural joint. Increasingly, a titanium alloy containing 6% aluminum and 4% vanadium is being used as the surgical implant material because it is superior to others in properties such as corrosion resistance, mechanical properties, bone match, and biocompatibility. The alloy's orthopedic use is limited mainly by its tendency to corrode and wear away when attacked by body fluids during its motion within the polyethylene cup. As a result, it releases metallic debris that can inhibit mobility, cause inflammation around the joint, and, in the long run, induce adverse systemic effects such as possible disorders of the liver or pancreas.

Using an apparatus designed to simulate the mechanical and chemical environment within the body's hip joint, Jim Williams of the Solid State Division, in collaboration with Raymond Buchanan of the University of Alabama at Birmingham, has demonstrated that implanting nitrogen ions in the titanium alloy makes it 1000 times more resistant to corrosive wear in the body. One factor that may contribute to this greatly increased resistance is implantation-produced surface hardening. Implantation can make the surface harder so that titanium oxide particles wiped from the surface cannot further abrade the surface and cause additional release of metallic debris.

Ion-beam processing also shows promise for improving surface interactions between surgical implant materials in other ways, including increased adhesion between components and reduced friction in artificial knees. As evidence of technology transfer, makers of surgical hardware are now testing the ion-implanted components.

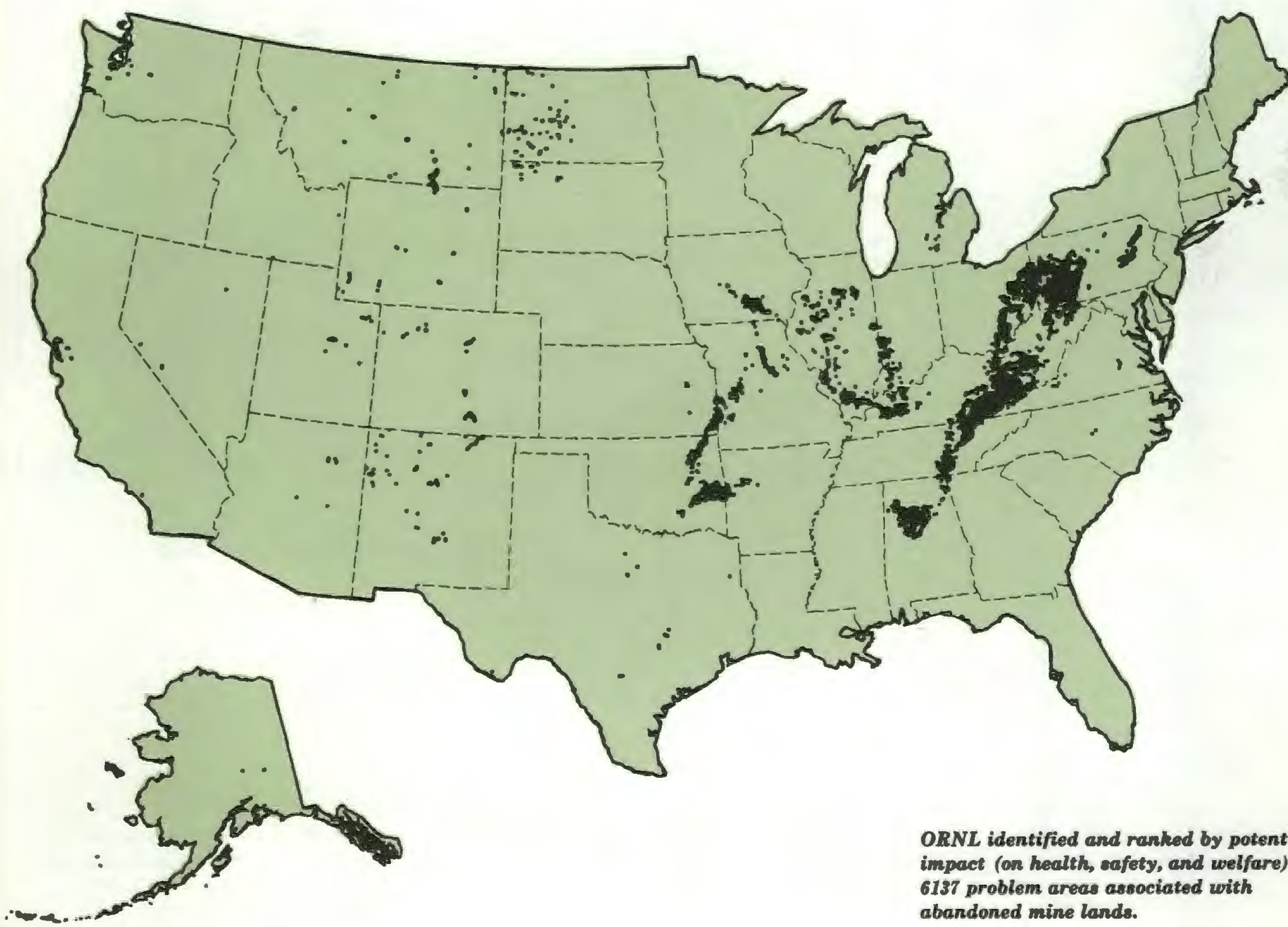
An important implication of this work in improving the titanium hip joint is the demonstration that surface properties can be altered without causing an undesirable side effect on carefully selected bulk properties of an alloy. Thus manufacturers can choose an alloy for its desired mechanical properties and then modify its surface to add or improve another key characteristic, such as resistance to corrosion.

ORNL Ranks Human Problems Created by Abandoned Mine Lands

In 1977 Congress passed the Surface Mining and Control Act, which provides for the repair of damage created by abandoned mines, through a severance tax on coal extracted from surface mines. ORNL was approached by the Office of Surface Mining (OSM) in the U.S. Department of the Interior for assistance because of our interest in applying satellite imagery and other remote-sensing tools to assessing the environmental impacts of strip mines. At that time, abandoned mine lands were thought to pose mainly environmental and aesthetic problems, such as acid pollution of streams and land scars like those found in the nearby Cumberland Mountains.

However, the federal legislation puts a clear emphasis *not* on the adverse environmental impacts of abandoned mines but on their potentially harmful effects on people's health, safety, and general welfare. Thus, in this example, the scale derives from the scope of a congressional mandate and the broad dimensions of the problem it was designed to correct. After studying the 1977 act, we persuaded OSM that the approach to the problem should be quite different from the approach we and OSM had originally expected to take. Rather than apply imaging technology, we agreed that a national inventory should be designed to identify health, safety, and general welfare problems as well as environmental problems on a state-by-state basis. ORNL also was asked to develop a set of criteria for ranking the severity of the problems.

First, we identified problem areas through inventory data submitted by the states and Indian tribes. A problem area is a geographical area that has mine-related problems that affect health (a polluted water supply, for example), safety (a vertical opening such as an abandoned air shaft, for example), and welfare (slide of waste material that blocks a road, for example). After identifying 6137 problem areas, we applied our criteria consistently to this information to produce a nationally standardized data base. An important part of the process involved a ranking of each problem according to severity of impact—that is, whether it represented an extreme danger, serious threat, or need for environmental restoration. Finally, all of the data and



ORNL identified and ranked by potential impact (on health, safety, and welfare) 6137 problem areas associated with abandoned mine lands.

evaluations were subjected to a rigorous critique for quality assurance.

Our synthesis of diverse data from multiple sources involved interagency, federal-state, and interinstitutional cooperation on a broad scale and over a significant period. Our results showed that more than 77% of the cumulative (or weighted) impact on people's health, safety, and general welfare occurs in the eastern anthracite and bituminous coal regions. Pennsylvania was found to be the most heavily impacted state, with 36% of the total problem areas and 26 of the 53 worst. The data show that only 12% (167) of the total number (1369) of the health, safety, and general welfare problem areas account for more than 83% of the projected reclamation cost.

This dangerous coal-loading facility and abandoned car in West Virginia are in one of the problem areas identified by ORNL.

The overall project, a collaborative effort of ORNL, Tennessee Valley Authority (TVA), East Tennessee State University (ETSU), and Lockheed Missiles and Space Company, Inc., took four and a half years, from January 1979 through August 1983. The cost was $13 million, including $6.6 million spent by the states and Indian tribes to collect the data. Principal contributors were Bob Honea, Carl Petrich, Dick Rush, and Al Voelker of the Energy Division; Dick Durfee, Bob Edwards, and Don Wilson of the Computer Sciences Division; Paul Baxter and Kingsley Taft of TVA; C. E. Tanner of Lockheed; and N. S. Fischman and R. W. Peplies of ETSU.

Despite considerable difficulties in data collection, standardization, and quality assurance, ORNL's inventory is a good representation of health, safety, and general welfare problems and is being used by OSM in carrying out its legislative mandate. The inventory was applied, for example, in deciding how to allocate discretionary money among the states and tribes. From our data analysis we concluded that enough tax money will probably be raised to correct all of the health, safety, and general welfare problems, provided that the money is allocated wisely. The estimated cost to remedy those identified problems is in the range of $0.8 billion to $1.6 billion. The funding would pay for such "fixes" as removing sources of water pollution, covering or filling abandoned mine-shaft openings, and removing rocks and other material that block roads. Although it is doubtful that enough money will be left to repair all environmental damage, considerable progress toward land reclamation can be made.

ORNL participants in the inventory of problem areas associated with abandoned mines are (from left) Richard Durfee, Don Wilson, Al Voelker, Dick Rush, Bob Edwards, Bob Honea, and Carl Petrich.

Large Coil Test Facility: 3 Superconducting Magnets Installed

A worldwide industrial technology base, a multinational collaboration through an International Energy Agency (IEA) agreement, an $80-million hardware investment by the United States alone, and ultimately a decade of effort make the development of magnets for the fusion program a notable example of large scale. This effort, whose purpose is to ensure an adequate scientific and industrial base for the design and fabrication of the large superconducting magnets required for power-producing fusion reactors of the future, has as a central element the Large Coil Test Facility (LCTF) at ORNL.

ORNL has had a major role in the design and procurement of three of the six coils that will be tested in the LCTF as well as in the planning, design, construction, and operation of the test facility. During 1983 several significant milestones were achieved. Construction of the facility was completed and accepted, the first two of the six coils were installed, and operation was started. Facility operation is itself a significant accomplishment because it involves a refrigeration system, capable of chilling the magnets to almost absolute zero, that is extending the state of the art of cryogenics.

ORNL is acting on behalf of DOE as the operating agent for the International Large Coil Task. Participants also include West Germany's Kernforschungszentrum Karlsruhe (for EURATOM), the Japan Atomic Energy Research Institute, and the Swiss Institute for Nuclear Research, each now represented here in the LCTF testing and analysis group. Operation of the LCTF in support of the coil testing program is carried out by a group of 16 trained and certified supervisors and operators in the Fusion Energy Division.

The Task's purpose is to support confident selection of the toroidal field coils that will confine the plasma fuel of future tokamak fusion reactors. Because they consume little electrical energy in producing magnetic fields, superconducting coils will allow fusion reactors to produce useful amounts of power. Copper magnetic coils, on the other hand, have an ohmic resistance that would cause them to consume more power than the plant could generate. Although the superconducting magnet system envisioned for fusion plants will reduce energy use and costs, the system itself will be quite expensive. Therefore, substantial investment in developing and testing different coil designs can be justified, because even small gains in efficiency and reliability will cut future costs greatly.

A 40-ton superconducting magnet coil produced by General Dynamics–Convair is lowered into the vacuum vessel of the Large Coil Test Facility in August 1983. Facility shakedown and installation of other test coils in 1984 will lead to tests of an array of six coils in 1985.

Of the total U.S. investment of $80 million, $36 million was spent at ORNL to construct the LCTF. At its heart is a test stand, holding up to six coils in a toroidal array and enclosed in a stainless-steel vacuum tank 12 m (40 ft) tall and 11 m (35 ft) in diameter. The vacuum tank and its superinsulating "cold wall" will act as a huge thermos bottle, allowing the coils to be cooled to 4 K. Each of the six D-shaped magnets to be tested weighs 40 metric tons and measures about 6 m (20 ft) tall and 5 m (15 ft) wide. Other key components are a helium refrigeration system, used to cool the magnets internally; a liquid nitrogen system, which provides cooling for the cold wall; power supplies; and computerized control, diagnostic, and data acquisition systems.

Under the IEA agreement, the United States is providing the test facility and three coils (being built under subcontracts with General Dynamics, General Electric, and Westinghouse). EURATOM, Japan, and Switzerland are providing one coil each (built by Siemens, Hitachi, and Brown-Boveri, respectively) at their expense. All participants will share in the information that is obtained.

ORNL and the Engineering Division wrote the coil specifications so that all six coils would fit in the facility and work together to create a magnetic field of at least 8 Tesla. Beyond those requirements, the internal design was left to the individual teams. The results reflect two different approaches to the use of liquid helium to achieve reliable, economic superconducting magnets—somewhat analogous to the use of pressurized or boiling water to cool nuclear fission reactors. In one approach, the conductors are internally cooled by pressurized helium; in the other, the conductors are immersed in a pool of boiling helium. A goal of the Large Coil Task is to compare the cost and performance of these two approaches under actual operating conditions in the LCTF.

The first integrated operation of the facility, with the Japanese and General Dynamics–Convair coils in the test stand, began in December with the evacuation of the large vacuum vessel. The purpose was to determine how well the facility systems work and to provide preliminary information on the performance of the two coils. The plan was then to shut down to install the remaining four coils and to make any necessary improvements in the facility. This plan was revised after helium leaks appeared in the General Dynamics coil during the first cooldown. Now the Swiss coil, which had been delivered in the meantime, is being installed before the facility shakedown and preliminary coil tests.

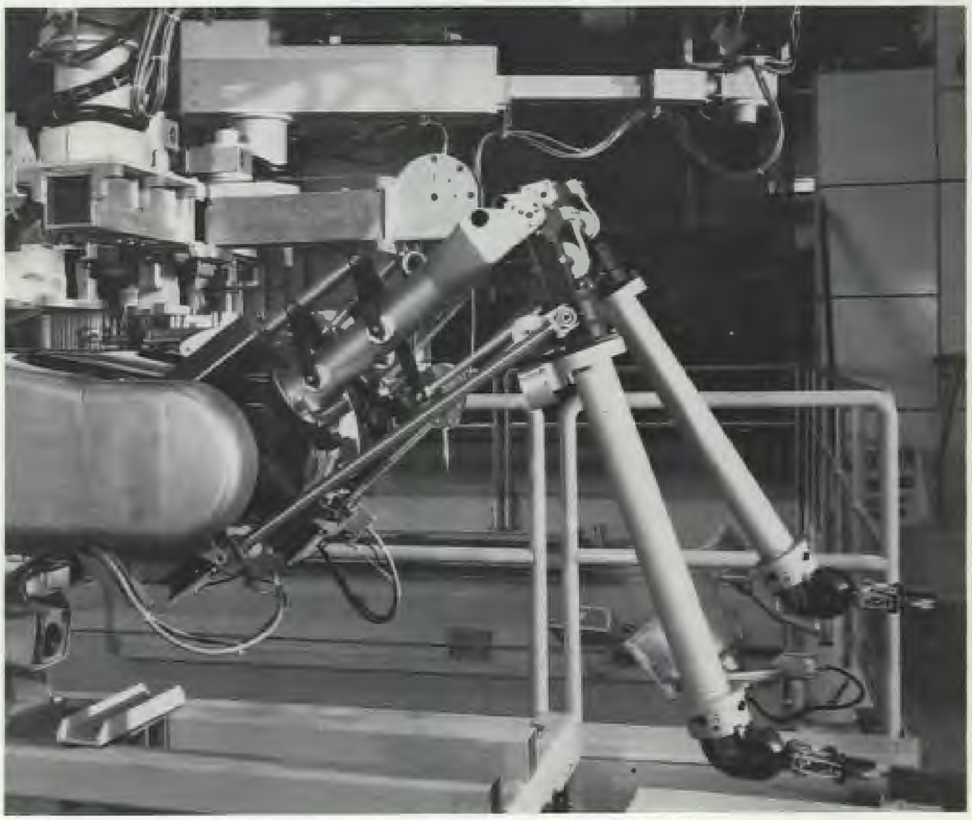
Key contributors to the large-scale magnet development activities at ORNL are Paul Haubenreich, international representative and manager of the U.S. program, Martin Lubell, John May, William Fietz, James Luton, Robert Bohanan, and Keith Kibbe of the Fusion Energy Division; and Howard Miller, John Monday, Phillip Thompson, and Ted Ryan of the Engineering Division.

Breeder Reprocessing Engineering Test To Use ORNL-Designed Equipment

This final theme-related example is another large-scale engineered system designed to play a crucial role as a proof test and demonstration of a major high-technology development effort. Called the Breeder Reprocessing Engineering Test (BRET), this project will demonstrate advanced nuclear fuel reprocessing concepts in a highly radioactive environment; its focus will be the closing of the fuel cycle for the Fast Flux Test Facility in Washington and for a future breeder reactor. The project represents the culmination of a decade of effort by the ORNL-managed Consolidated Fuel Reprocessing Program to develop advanced concepts of making new nuclear fuel elements from spent fuel.

A unique aspect of BRET will be the use of totally remote maintenance based on the advanced servomanipulators under development here. From this ORNL development has stemmed a whole new look at the application of remote operation and maintenance technology to reprocessing in the United States and a significant move in that direction in both West Germany and Japan.

In support of BRET, which will be located at the Fuels and Materials Examination Facility at Hanford Engineering Development Laboratory (HEDL), ORNL will be responsible for designing, developing, procuring, and testing all of the reprocessing equipment. This effort will represent about 40% of a projected $500-million



This servomanipulator, made by a Minnesota firm, reflects contributions by ORNL researchers to the design of its control system. The unit is being used to functionally test maintenance techniques and provide data to assist in the development of an advanced servomanipulator that will be used for the Breeder Reactor Engineering Test at Hanford Engineering Development Laboratory.

project over a six- to seven-year period. BRET is seen as an important element in future U.S. strategy for nuclear-power and fuel-cycle development.

ORNL's contributions to this collaboration with HEDL will draw on prototype equipment and facilities developed as part of the Laboratory's nonradioactive Integrated Equipment Test (IET) facility, which is now in operation. The advanced state of IET components makes it possible to engineer systems rapidly for BRET, with only a limited engineering development program. The IET facility combines two key elements of the advanced technology development—a remote operation and maintenance demonstration, where the mechanical head-end of the reprocessing sequence is located, and the integrated process demonstration, where portions of the follow-on chemical separation stages are located. The first began test operation in 1982, and the latter is scheduled to go on line later this year.

ORNL will design, procure, and test all of the equipment to be used in BRET and will carry out any necessary development work. We will design the prototype disassembly and shearing system, which includes lasers used to slice off ducts and nozzles on fuel rod bundles; this system has been investigated and incorporated into the IET design. We will also design for BRET a continuous rotary dissolver system similar to the IET prototype that has been undergoing evaluation for several years, logging more than 2000 h of operation.

An alternative approach to manually collecting each day some 60 highly radioactive process samples containing uranium and plutonium is a self-propelled, remotely operable robot vehicle. A prototype, currently being tested in IET, will be the basis of the sample collection system used in BRET. Finally, the remote maintenance system developed for IET allows maintenance of radioactive in-cell equipment using mobile servomanipulators displayed on television; the servomanipulators provide the operators with force-reflection feedback, which gives them greater dexterity and flexibility in performing the maintenance operations. Similar systems will be used at BRET. Advanced servomanipulators under development offer advantages over existing models. They eliminate the weak links of present manipulators—cables and tape drives—by replacing them with gears and torque tubes. Furthermore, because modular construction is used for these systems, any of the major components can be replaced in the cell by using another manipulator, thereby eliminating the need to extensively decontaminate manipulators before repairing them.

A number of major objectives of the Consolidated Fuel Reprocessing Program, for which ORNL has the technical lead within DOE, will be accomplished through BRET. These objectives include (1) operating a realistic test of advanced technology with irradiated fuel; (2) reducing the technical risks posed by the breeder energy option, by closing the fuel cycle in concert with developing the base technology; (3) recovering plutonium from spent nuclear fuel, thus reducing the need to procure plutonium to fuel breeder reactors; and (4) providing the technical framework for U.S. participation in international agreements in this technology, including the important goal of formulating adequate safeguards.

The contributors both to BRET and to the ambitious program of technology development on which it is based include Bill Burch, Sam Meacham, Orlan Yarbro, Grant Stradley, Melvin Feldman, Norbert Grant, E. D. North, and William Groenier of the Fuel Recycle Division; Baird Bottenfield of the Engineering Division; and Bill Hamel of the Instrumentation and Controls Division.

Next: Technical Highlights

Dan Kingston operates the servomanipulator remotely by viewing on television the manipulator and objects to be moved. The manipulator provides force feedback, which allows the operator more dexterity and flexibility in performing remote maintenance operations.

Steps Taken To Alter Enzyme To Increase Crop Yields

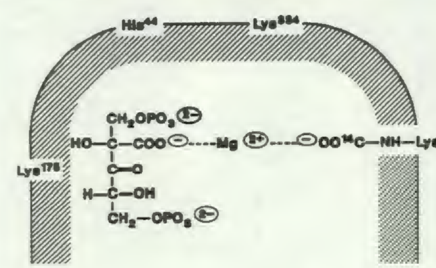
Because trees and other biomass crops are renewable energy sources, ORNL biochemists have a special interest in an enzyme that plays a vital role in the growth of green plants. Called ribulosebisphosphate carboxylase, the enzyme indirectly uses the energy of sunlight to bring about conversion of atmospheric CO_2 into carbohydrates (10^{11} tons annually on a global basis, produced by 10^7 tons of the enzyme itself). Unfortunately, this CO_2-fixation enzyme also uses oxygen to break down carbohydrate, thereby wasting energy and decreasing the yield of carbohydrate. Thus plant growth is inhibited; in fact, the Jekyll-and-Hyde ability of this enzyme to catalyze both useful and counterproductive reactions can cut some plant yields in half. If plants are exposed to elevated CO_2 levels and reduced oxygen concentrations, however, their growth is more rapid.

Because it is obviously impractical to decrease the oxygen level in the atmosphere, the logical strategy is to modify the enzyme in a beneficial way so that oxygen no longer inhibits plant growth. During the past year, Fred Hartman and associates in the Biology Division have made substantial progress in elucidating certain structural features of the CO_2-fixation enzyme that might suggest how to reduce the undesirable effects of oxygen. Collaborating with Hartman are Claude Stringer of the Biology Division and Eva Lee of the University of Tennessee–ORNL Graduate School of Biomedical Sciences.

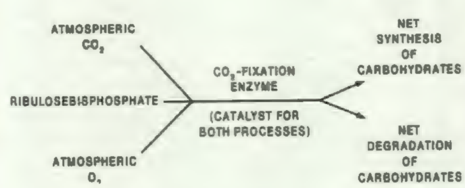
Using sophisticated protein-modifying agents called affinity labels, the researchers have identified, located, and schematically represented the enzyme's constituent amino acids that participate in catalysis. Also, through comparative sequence studies of evolutionarily diverse species of CO_2-fixation enzyme, they have confirmed that the structures of these catalytic site regions are very similar. Now that the catalytic site has been partially characterized, methods of genetic engineering will be able to generate mutant forms of the enzyme that may be deficient in catalyzing the oxygenation reaction.

Our long-term goal is to improve plant yields for food and biomass production. The ability to characterize structural and mechanistic features of the enzyme should provide the experimental basis for systematically altering the chemical environment at the catalytic site, which in turn may diminish the effects of oxygen. Once a mutant enzyme is achieved, the next step would be to incorporate a gene for the mutant enzyme into experimental plants. Such genetically engineered plants could have greatly increased yields.

Fred Hartman and Eva Lee purify the carbon-dioxide-fixation enzyme by column chromatography.



This schematic shows the site of the carbon-dioxide-fixation enzyme where catalysis occurs. Genetic engineering could alter this site and ultimately improve plant yield.



Oxygen inhibits the performance of the enzyme designed to convert atmospheric carbon dioxide into carbohydrates in green plants. If the enzyme could be modified so that it did not catalyze reactions involving oxygen, plant yield could be increased.

Simulation Aids Understanding of How Radiation Damages Cells

The effects of low levels of ionizing radiation on biological systems are a continuing concern to both science and society. Scientists have long tried to understand how radiation damages the living cells it penetrates, sometimes causing genetic mutations or cancer. Recent calculations in the Health and Safety Research Division (HASRD) have shed important new light on details of the initial physical and chemical changes produced by the passage of a charged particle through matter. ORNL's studies follow the subsequent chemical changes through the first microsecond after irradiation, when the reactions are essentially over.

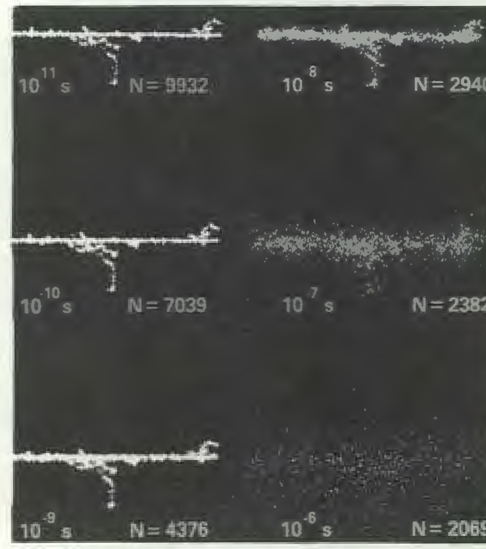
The experimental data taken over the last two decades in HASRD's radiation physics program were used to calculate the initial changes produced by incoming charged particles. Then, using Monte Carlo techniques, the HASRD researchers developed a computer code for the transport of radiation through condensed matter (solids and liquids).

According to the calculated results, the passage of a charged particle and all of its secondaries produces the initial changes in a local region around the particle's track in 10^{-15} s. Diffusion and chemical reactions begin at about 10^{-11} s. The code determines the position and chemical identity of each species produced initially by the charged particle. The calculations follow each individual species through the prechemical stage to 10^{-11} s and then through the diffusion and chemical reaction stages to times of about 10^{-6} (1 μs) after passage of the charged particle.

This work represents the first time that calculations have been done to connect the physics and early chemistry that follows irradiation. Chemical yields obtained by the calculations appear to be in good agreement with measured values.

The HASRD researchers have used their Monte Carlo code to simulate in complete detail the passage in water of a charged particle and all its secondaries. In one example, the development of an 8-MeV alpha particle track in liquid water shows the positions of the reactant species and the number of species remaining at various times. The reactant species are the hydroxyl radical (OH), the hydrogen (H) radical, the hydronium (H_3O^+) ion, and the hydrated electron.

The total length of the alpha track segment is 0.7 micron, about the diameter of the nucleus of many cells. According to some models, biological damage is enhanced by the close proximity of reactant species within such a distance. The actual locations of all species along the alpha particle track between 10^{-11} s and 10^{-6} s are obtained in detail from the HASRD calculations. Such information can be used to determine mechanisms of biological damage induced by radiation.



This stop-action code defines which reactions take place along the track of alpha-particle radiation during the first microsecond of its penetration into liquid water. The black dots leaving the track are secondary electrons.

Contributors to this study are Harvel Wright, Jim Turner, Bob Hamm, and Rufus Ritchie of HASRD and John Magee and Aloke Chatterjee of Lawrence Berkeley Laboratory.

In addition to using this approach to help understand how radiation changes living tissue, the HASRD researchers are applying it to the study of radiation-induced changes in electronic microcircuits. Memory chips used in Earth satellites are so small that passage of a single cosmic ray can change a chip's information content. The researchers are trying to determine the specific radiation conditions that could cause these memory upsets; such information could lead to recommendations on how to protect the chips from radiation damage.

Contributors to the study of irradiation effects in condensed matter include (from left) Harvell Wright, Jim Turner, Rufus Ritchie, and Bob Hamm.

A Better Radionuclide Generator To Detect Infant Heart Defects

When radioisotopes are used in medical diagnosis, short-lived radionuclides are desirable because they decay quickly, thus exposing patients only briefly to potentially hazardous radioactivity. Radionuclide generators are convenient sources of these short-lived "daughter" radionuclides, which are formed by the radioactive decay of a longer-lived "parent." In 1983 the nuclear medicine group in HASRD developed a new, improved generator for iridium-191m, a radioisotope whose 5-s half-life and other properties make it desirable for diagnosing heart ailments in both children and adults.

Since 1980 ORNL has supplied the parent osmium-191 radionuclide (which has a 15-d half-life) to Children's Hospital in Boston. The osmium-191 isotope used in the iridium-191m generators is produced in ORNL's High-Flux Isotope Reactor (HFIR) by neutron irradiation of calutron-enriched osmium-190.

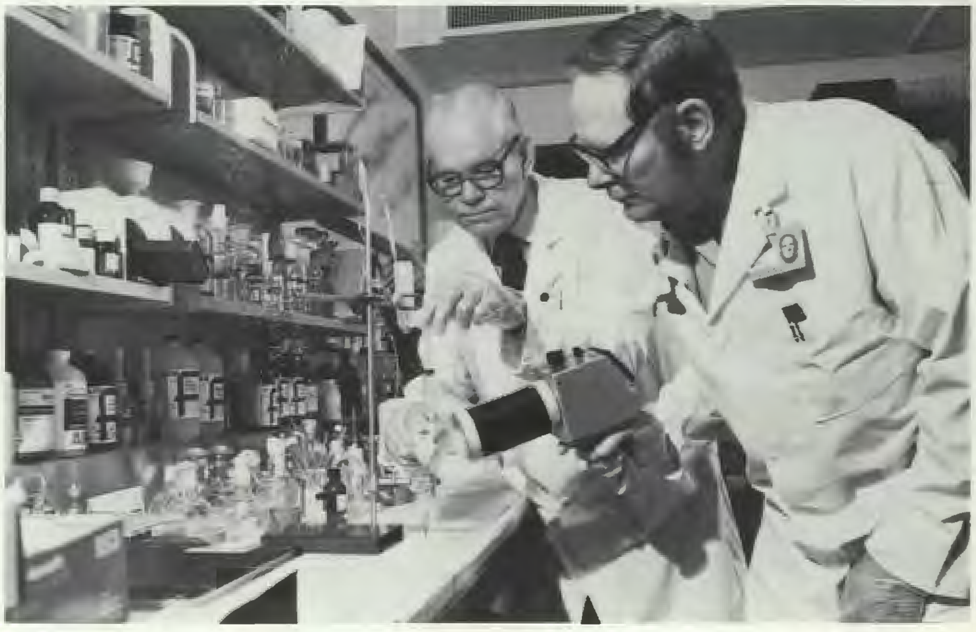
At the Boston hospital the clinical generators are prepared for producing the daughter iridium-191m, which is used to evaluate heart disease in children. Advanced gamma-camera imaging systems can take 12 to 15 pictures per second of the radioisotope as it is carried along in the patient's bloodstream. Abnormal passage of blood between the heart chambers can thus be easily detected and evaluated by this noninvasive technique, which helps identify patients who need surgery to close the hole (shunt) between the chambers. Iridium-191m is particularly well suited for children because its short half-life results in a very low radiation exposure and because the radioisotope clears within minutes for repeat studies. Each year in the United States some 20,000 children are born with the congenital heart defect that can be diagnosed in this way.

The disadvantages of the current generator system are that it has only a modest yield and that, with repeated use, the parent osmium begins after a few days to wash through the ion exchanger with the eluting solution, thus contaminating the iridium-191m. When this "breakthrough" occurs, the iridium generator is considered no longer useful for clinical studies because the contaminated product would significantly increase the patient's exposure to radiation.

The goal of our work has been to find a way to increase the iridium-191m yield and prevent breakthrough, thereby extending the useful life of the generators from days to weeks and ensuring patient safety. To be available for a large patient population, the system also should be inexpensive.

The new ORNL system, a product of systematic evaluations of 41 different ion-exchanging materials, appears to meet these requirements. The studies demonstrated that osmium-191 in one of its oxidation states can be tightly bound and that the elution yield of iridium-191m can be increased from 10% to 40%. More importantly, the breakthrough is low, and the generators retain their desirable properties for several weeks. Preclinical tests are now in progress; the next step will be to supply the new generator to medical cooperative investigators for certification for testing in humans.

Several pharmaceutical firms are interested in manufacturing iridium generators because of their relatively long useful life, low cost, and ability to produce a short-lived radioisotope that gives an extremely low radiation dose to patients and a high yield of gamma photons at an energy level that is efficiently detected. Developers of the generator system have been Russ Knapp and Tom Butler of HASRD and Claude Brihaye of the University of Liege, Belgium.



Tom Butler adjusts an experimental generator while Clarence Guyer monitors the operation with a "cutie pie." The generator contains osmium-191, which decays to iridium-191m, an isotope with a 5-s half-life that is now being used to identify heart defects in infants. Butler and his colleagues have made a safer, more efficient generator.

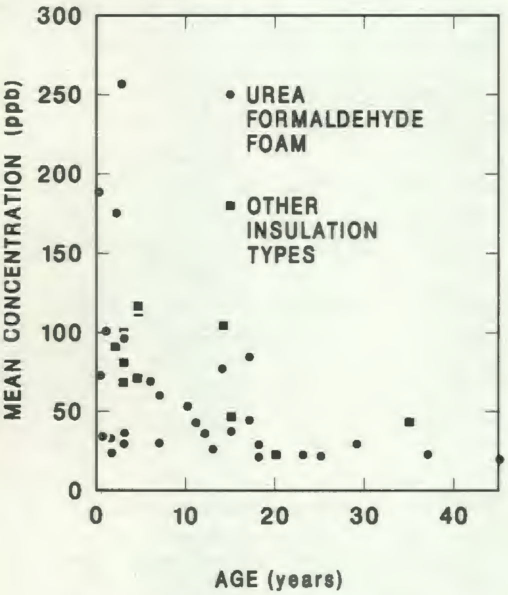
ORNL Measures Indoor Air Quality in Local Homes

Much of the air we breathe comes from inside our own homes, yet most scientific studies have concentrated on the quality of outdoor, not indoor, air. The quality of indoor air, however, may be worse than that of outdoor air; in some cases, it is lower in buildings that use energy-saving measures. For example, "tightening" measures such as vapor barriers and caulking, which reduce the rate of outdoor air infiltration and heat leakages, may also keep pollutants inside for longer periods, thus increasing human exposure. Also, energy-saving heating methods such as space heaters and wood stoves are potential sources of indoor air pollution.

To better understand the chemical composition of the home atmosphere, in 1983 a group in HASRD completed a four-season monitoring and analysis of 40 homes in the Knoxville–Oak Ridge area. All participants were volunteers, and the homes were selected to represent a range of ages and construction, heating and cooling methods, and insulation types. Monthly sampling (for formaldehyde only), plus one or two more detailed 6-h surveys in each home, focused on average concentrations and seasonal fluctuations in several air-quality indicators. These indoor pollutants included *formaldehyde*, which is emitted from pressed-wood building materials, furniture products, and urea-formaldehyde foam insulation; *radon*, a naturally occurring radioactive gas that can seep from underground rocks into homes; *carbon monoxide*, which is discharged from kerosene heaters, fireplaces, and gas appliances; *nitrogen oxides*, which are emitted by gas stoves and heaters; and various *hydrocarbons* from products such as gasoline and cleaning fluids. Information was also collected on air-exchange rates, weather conditions, and structural and consumer products in each home.

Although the sample was small and the locale limited, this baseline study for the Consumer Product Safety Commission was a first step toward better estimates of total individual pollutant exposures (outside and in) and, ultimately, better correlations between

Don Womack sets up instruments in a study home to measure indoor levels of combustion gases (nitrogen oxides and carbon monoxide), particulates, and volatile organics.



Formaldehyde levels in homes vary with age and insulation type. Some newer homes without urea formaldehyde foam insulation (UFFI) have higher concentrations of formaldehyde (which can irritate the eyes, mucous membranes, and lungs) than do older homes with UFFI.

exposure and health effects. Among the findings were the following.

- Formaldehyde concentrations were approximately twice as high in homes less than five years old as in older residences.
- More than half the homes exceeded a recommended formaldehyde limit of 0.1 ppm at least once during the year.
- Approximately 30% of the homes had radon concentrations greater than an EPA guideline of 4 pCi/L.
- Homes built on the less porous sediment of valleys had significantly lower radon concentrations than those located on area ridges, which consist of porous dolomite rock over uranium-bearing shale formations.
- The concentration of volatile organics (hydrocarbons) in indoor air frequently was more than ten times as high as that in outdoor air.
- Carbon monoxide and nitrogen oxide levels in the homes generally were below outdoor levels, except where unvented heaters or appliances were used.
- Rates of air exchange were about twice as high (when fans were operating) in homes with central heating and cooling, apparently because of the considerable leakage in duct systems.

After the considerable resources expended to reduce and control outdoor air pollution in recent years, this type of study represents a new and important air-quality frontier. Members of the team from HASRD's Health Studies Section were Alan Hawthorne, Dick Gammage, Charles Dudney, Brian Hingerty, and Dan Schuresko, assisted by collaborators from the University of Tennessee.

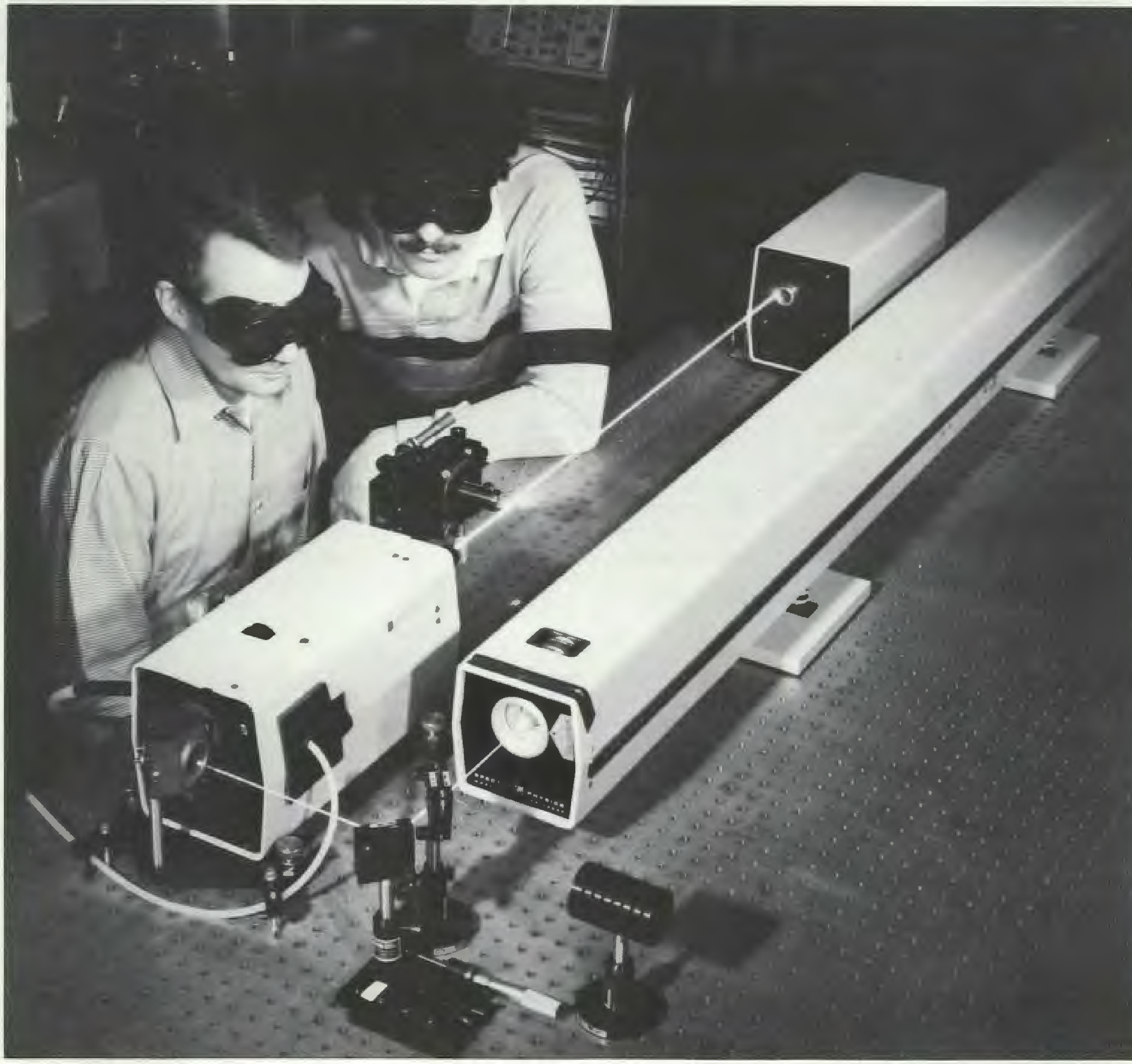
Aided by Crystal, Dye Laser Fine-Tunes Itself

A new development in the Analytical Chemistry Division involving a continuous-wave (CW) dye laser and a barium titanate crystal could lead to changes in the design of lasers. Bill Whitten and Mike Ramsey have discovered that the holographic, or internal reflection, properties of the crystal can feed laser light back to the laser, causing it to continuously change the wavelength of its emitted light and to achieve very narrow linewidths (a pure color rather than a mixture of hues of one color). This "self-scanning" feature, which allows a laser to fine-tune itself automatically and repetitively at higher-than-normal resolution, could lead to the development of new lasers for analytical spectroscopy. Because these lasers would need fewer mechanical parts and no manual operation, they might be suitable for use in remote areas and aboard orbiting space laboratories.

To identify and quantify the amount of a specific gas in a gas mixture, scientists can shine laser light of a specific wavelength that is absorbed by the gas in question. Measuring the amount of light absorbed indicates how much of the gas is present in the mixture. When conventional lasers are used in optical absorption spectroscopy, a person or computer has the job of scanning—that is, tuning the laser by adjusting a grating or filter to get the desired wavelength. To achieve the greater resolution possible with even narrower linewidths, the laser operator or computer must also change the tilt of a pair of parallel mirrors called an etalon.

The self-scanning phenomenon, discovered at ORNL, eliminates the need for laser operators or computers to tune the scanning element and etalon. Whitten and Ramsey found that in addition to being mechanically simpler and more convenient, this laser-crystal combination can scan over a band of wavelengths extending over 250 Å and can produce a linewidth as narrow as 0.05 Å. Such high resolution over this broad range of wavelengths cannot be easily achieved by conventional lasers; it can be done only by resetting the etalon after each wavelength scan of 2–3 Å.

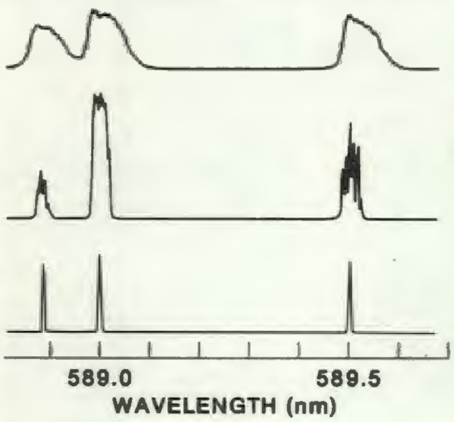
A conventional dye laser without tuning elements can have a linewidth of as much as 20 Å. But if a barium titanate crystal is added to the laser configuration, the modified device can achieve a linewidth as narrow as 0.05 Å, a 400-fold improvement in resolution.



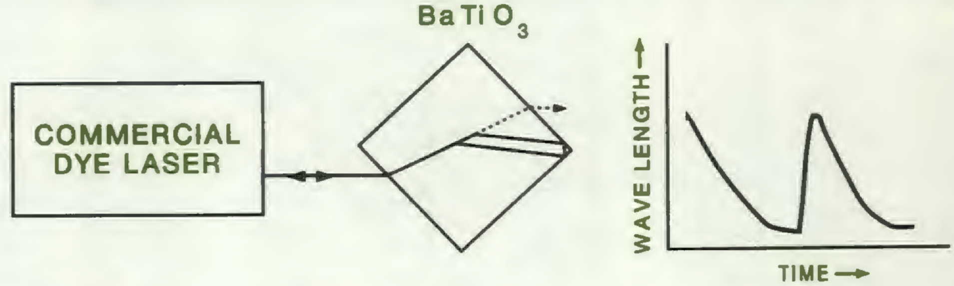
Because of its high resolution, the self-scanning dye laser can potentially identify and quantify two gases in a mixture that absorb light of about the same wavelength. This new laser may even be selective enough to differentiate between isotopes of the same gas.

When the laser light shines on the barium titanate crystal, a hologram is created. A hologram is normally defined as a three-dimensional picture that is made by interference patterns produced by split beams of laser light. The ghostlike image of Princess Leia in the movie *Star Wars* is a familiar example of a hologram. In the case of the barium titanate single crystal, the hologram produced is a kind of "mirror" that causes retroreflection of the laser light shone into the crystal. This holographic process is being studied at ORNL and several other laboratories. It is

Bill Whitten (front) and Mike Ramsey operate a dye laser that continuously changes the wavelength of its emitted coherent light because of the presence of a barium titanate crystal that reflects the light back into the laser.



A self-scanning dye laser gives a higher resolution of sodium D lines (bottom spectrum) than is obtained by a conventional dye laser (top two spectra).



Laser wavelength scanning is automatic and continuous because of the optical feedback from a holographic reflector formed in the barium titanate crystal. Lasers that tune themselves could be useful for analytical spectroscopy in remote areas and aboard spacecraft.

speculated that the self-scanning phenomenon is caused by a spatial shift between the hologram and the light intensity pattern that produces it.

Whitten and Ramsey's observation that feedback from a barium titanate crystal causes automatic and repetitive wavelength scanning by a CW dye laser is expected to stimulate a large experimental and theoretical effort toward understanding the optical phenomena involved. Meanwhile, as they try to understand the holographic process and how laser light feedback induces self-scanning, they will examine the possible uses of this new laser configuration for analytical spectroscopy.

More Compact Varistor Could Protect High-Voltage Lines

A new development in the Metals and Ceramics Division promises an immediate and substantial gain for the nation's electric utilities in protecting high-voltage lines and other vital links of electrical distribution from destructive power overloads. This development could reduce the size of varistors, the massive ceramic surge arresters used in high-voltage switchyards, transformers, and transmission lines to short out electrical overloads resulting from lightning and other causes. The large size (up to 12 m, or 40 ft, in length) of conventional varistors has made it difficult to site them in urban areas. Smaller varistors could be particularly useful in congested urban areas, underground transmission lines, and energy-saving gas-insulated structures operating at extremely high voltages.

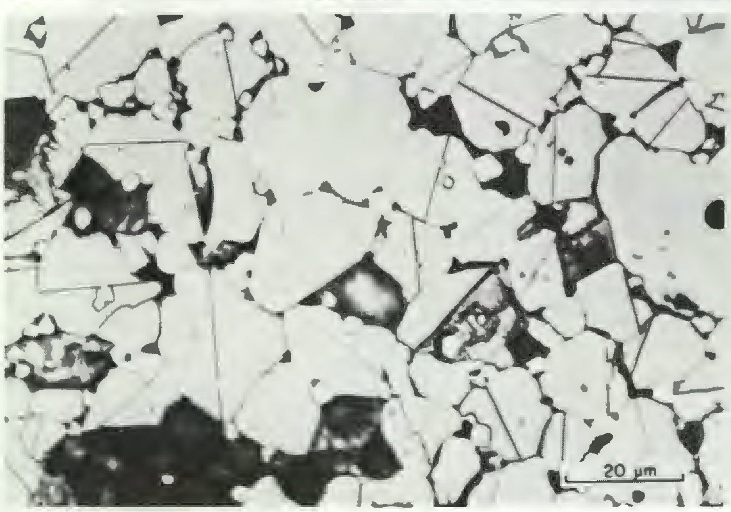
The devices themselves are non-ohmic—that is, they offer very high resistance for voltages below some critical value. When this value is exceeded (as when lightning strikes a transformer), the resistance becomes very low, allowing high currents to be carried safely to ground. Metal-oxide semiconducting varistors operate on the principle that certain dopants segregate to the grain boundaries; in so doing, these dopants create a blocking potential of the order of several volts per grain boundary. The critical voltage for a particular device is directly proportional to the number of grain boundaries from one end of the varistor to the other and is therefore governed by both grain size and overall thickness.

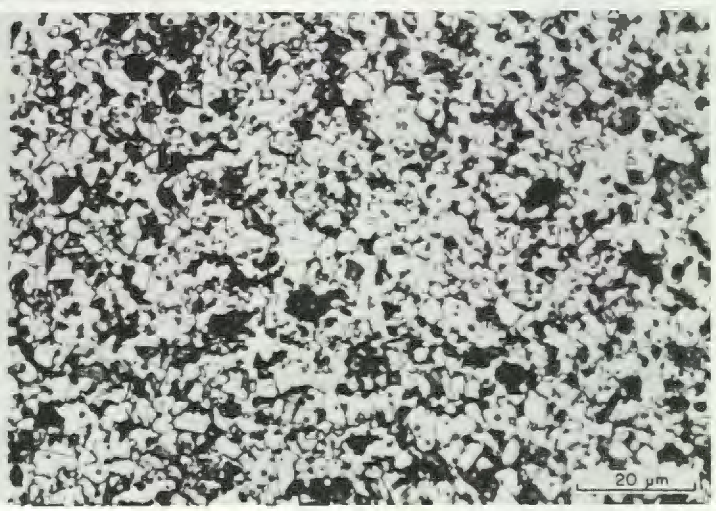
The ORNL development is based on advanced ceramic processing technology, which significantly reduces the particle size of the starting powder mixture and therefore reduces the grain size after processing. This ceramic processing technology includes sol-gel technology, which has been under development at ORNL for many years.

The goals of the ORNL research were to reduce the grain size of the typical bismuth-doped zinc-oxide commercial varistor and to achieve high density at lower processing temperatures (700–800°C vs 1400°C). The methods used were (1) synthesizing highly active powders by coprecipitation and/or sol-gel techniques and (2) hot pressing the ceramic powders in a highly reducing environment to achieve nearly theoretical density at 800°C or less. Heat treating after hot pressing results in the full development of non-ohmic electrical properties.

Robert Lauf of the Metals and Ceramics Division and Walt Bond of the Chemical Technology Division have developed a varistor with a grain size of less than 2 microns, compared to the average of 20 microns in current commercial devices. This approach of reducing the zinc oxide grain size has resulted in an expected gain in breakdown potential—approximately 4000 V/mm compared to 100 V/mm in the commercial material; in other words, for a given thickness, the finer grained material resists a voltage 40 times as great as that required for breakdown in

Robert Lauf (right) removes a varistor sample from a heat-treating furnace while Walt Bond looks on.





conventional varistors. This gain allows the use of a much smaller device for a given operating voltage; such a device might also have a faster response to very rapid transients. Related fundamental studies are designed to improve understanding of the mechanisms of varistor action and the relation between microstructure and electrical behavior.

If this development is used, the electric utility industry will benefit because it needs small varistors for congested urban areas, underground lines, and gas-insulated systems. Furthermore, the industry could save money because the smaller varistors would require fewer raw materials.

Varistor grain size is reduced by a factor of 5 (from 20 to 4 microns in diameter) by sol-gel technology at ORNL. A reduced grain size permits the construction of smaller surge arresters, which utilities may want to use in congested urban areas.

New Laser Facility Measures Particle Size and Mobility in Fluids

ORNL has developed a new laser facility that can measure the size and mobility of particles in fluids at high temperatures and pressures. The experiments performed at this facility are of particular interest to chemical engineers and ceramists.

Chemical engineers are interested in the size of particles in a fluid and fluid transport properties such as viscosity (resistance to flow) and diffusivity (mobility of molecules or particles in the fluid). The mobility of microscopic particles is governed primarily by the fluid drag, which opposes their motion. Because this friction depends upon the particle size and the fluid viscosity, measurements of mobility can provide either the particle size or the fluid viscosity. Information from experimental measurements can help engineers predict high-temperature transport properties important to new technologies such as coal processing to make liquid and gaseous fuels and chemicals.

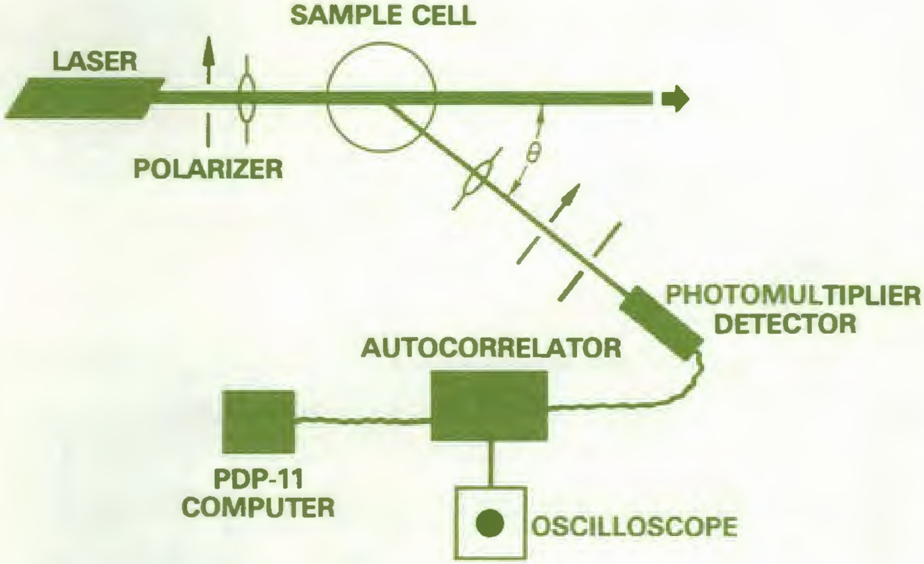
Ceramists are also interested in particle size because controlling the particle size can improve the properties of ceramics. Ceramics are corrosion-resistant, heat-resistant materials that could be used in high-temperature heat engines such as gas turbines. However, because the processing of ceramic powders is poorly controlled, conventional ceramics tend to be brittle and therefore have limited use in high-temperature environments. At ORNL and other laboratories, stronger ceramics are being made from fine-grained powders suspended in a fluid. Ceramists seek to control the size of these colloidal powders and the subsequent consolidation of material into a uniform structure that exhibits greater strength and other superior properties. To achieve this control, ceramists must be able to monitor particle size in the range from 10 Å (10^{-9}) to 1 micron (10^{-6}).

At ORNL an important new method for monitoring such microscopic phenomena is dynamic laser light scattering. Charles Byers and Dave Williams of the Chemical Technology Division have developed a new facility that can measure the size and mobility of particles in fluids at high temperatures and pressures. By measuring the light scattered from particles of known size, they have been able to determine fluid viscosities at elevated temperatures. Their high-temperature experiments have focused on typical compounds found in coal-processing solvents, such as tetralin and toluene. In addition, they have used laser light scattering to characterize ceramic powders and follow the nucleation (birth) and growth of crystals.

In a typical experiment, a fluid containing microscopic particles is placed in a sample cell. Because the sample is small (a few grams) and well contained, hazardous materials are easily handled. Light from the laser is focused onto the center of the cell. Most of the light passes through the sample; however, a small fraction bounces off the particles in the fluid. This scattered light is collected in a photomultiplier, which measures the light intensity.

Dave Williams (right) tunes a 2-W argon-ion laser, Ron Brunson records data, and Charlie Byers (left) checks the control panel. The apparatus on the table includes the laser, focusing lenses, and photomultiplier (tube next to Byers's hand). This laser facility can be used to measure the size and mobility of particles in fluids.

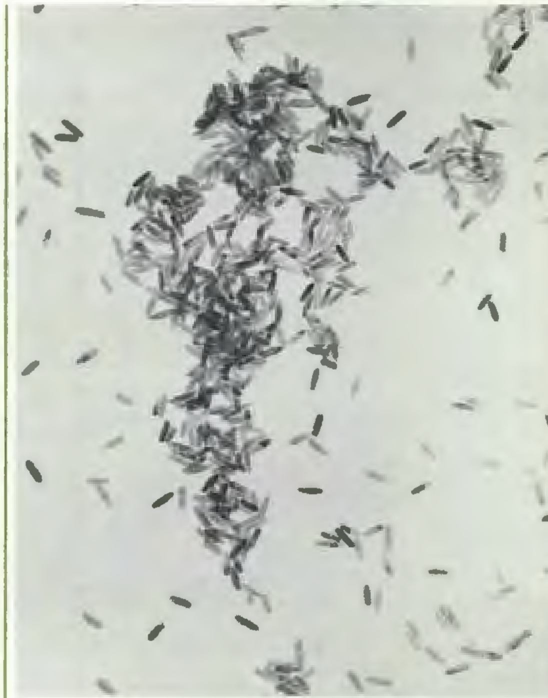
Light is scattered because the particles in suspension have a refractive index different from that of the fluid. The motion of the particles modulates the scattering intensity, producing a signal



In this schematic of a dynamic laser-light-scattering setup, most of the light passes through the sample cell, but a small portion is scattered from particles in the sample fluid. The scattered light is collected in the photomultiplier, which measures the light's intensity. Fluctuations in the intensity of the scattered light are analyzed in the autocorrelator, which receives signals from the photomultiplier; the oscilloscope shows the changes in the signal. More extensive calculations to determine fluid properties such as viscosities are performed in the computer.

that fluctuates with time. The fluctuations in the intensity of the scattered light are analyzed in the autocorrelator, which receives signals from the photomultiplier detector. As it gathers data on intensity fluctuations, the computer calculates particle size and mobility as well as fluid properties such as viscosity.

Because the assemblage of molecules that makes up an embryonic crystal scatters light differently than does the fluid in which the particles are suspended, dynamic laser light scattering shows promise in following nucleation and crystal growth processes. The growth of crystals as small as 200 Å is followed this way. Because of recent successes, Williams will continue to use the technique to measure particle sizes in powders for ceramics production. And Byers foresees the application of this technique for characterizing emulsions (such as oil-water mixtures) and tightly bound suspensions.



Laser-light-scattering measurements of the size of hematite (Fe_2O_3) particles correlate with electron-microscopy (EM) measurements. Because light-scattering measurements provide only one size parameter (diameter), these data must be corrected to account for particle shape, which can be directly ascertained by EM. Particle shape (rods, spheres, etc.) influences the drag and, hence, the mobility of the particle in the fluid in which it is suspended.

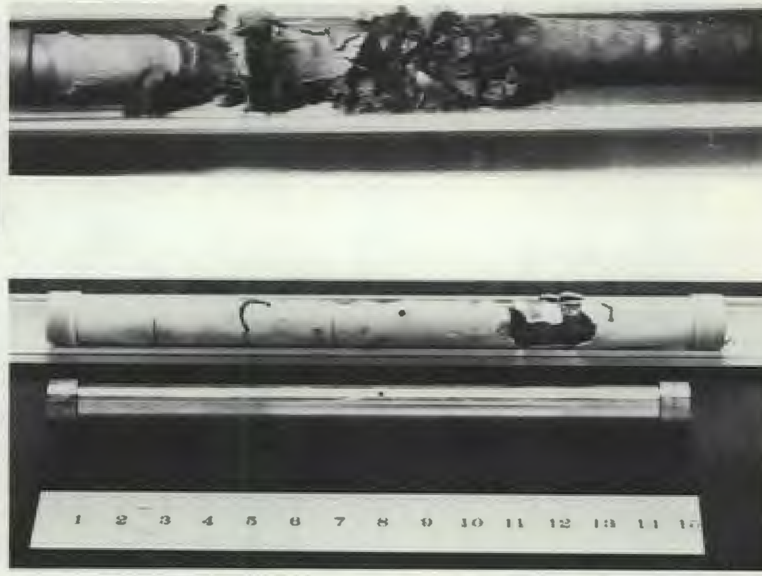
Fission Product Release from Reactor Fuel Determined at ORNL

Since the 1979 accident at the Three Mile Island nuclear power plant, there has been a growing need for realistic assessments of the amounts of radioactive materials that might be released from reactor containment buildings in the event of small loss-of-coolant accidents. The evaluation of this "source term" has been receiving worldwide attention. For example, emergency planners want to know if the release of radioactive iodine during nuclear plant accidents is much less than previously calculated; if so, evacuation of a large population after an accident might not be necessary.

Fortunately, reliable source term data can be obtained at an ORNL facility—the only one in the world that can be used to test high-burnup, light-water-reactor (LWR) fuel at temperatures as high as 2270 K. With funding from the Nuclear Regulatory Commission (NRC), researchers are measuring fission product release from Zircaloy-clad, high-burnup LWR fuels obtained from commercial pressurized-water reactors and boiling-water reactors. The test apparatus is operated by Chemical Technology Division staff members Morris Osborne, Jack Collins, Dick Lorenz, Jim Travis, and Charles Webster and a visiting investigator, Keith Norwood, of the Atomic Energy Research Establishment at Harwell, United Kingdom.

The 15-cm-long fuel specimens are heated in a flowing steam atmosphere while four radiation detectors continuously monitor the release of radioactive cesium and krypton. Releases of iodine and other less

Contributors to the fission product release study are (from left) Morris Osborne, Jack Collins, Charles Webster, Dick Lorenz, Jim Travis, and Keith Norwood.



The effects of steam heating on high-burnup irradiated fuel and on unirradiated specimens are shown here. The specimen at the top was irradiated for 20 min at 1700°C; as a result of complete oxidation from steam reactions and reaction with the uranium oxide fuel, the cladding expanded and split apart. The unirradiated fuel segment (middle) underwent less damage from steam heating for 30 min at 1700°C. An intact fuel segment is shown at the bottom.

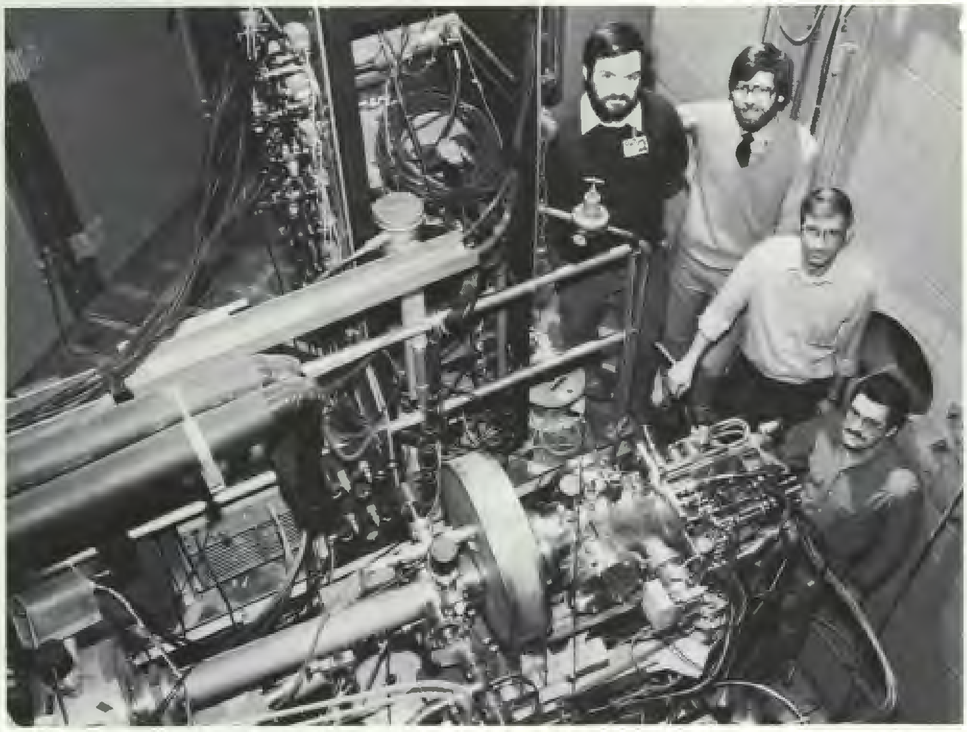
volatile fission products are measured at the end of the 20-min test by quantitative gamma spectrometry, neutron activation analysis, or spark source mass spectrometry performed by the Analytical Chemistry Division. Sectioning and posttest metallographic examination of heated fuel specimens is performed in the hot cells of the High Radiation Level Examination Laboratory.

Results show that during the first 20 min at a temperature of 2270 K, from 50% to 60% of the fission products cesium, iodine, and krypton was released from the fuel; this proportion is slightly lower than that predicted in a 1981 NRC technical review (published as NUREG-0772). Releases of less volatile fission products such as silver, tellurium, antimony, barium, and strontium are more difficult to measure; but results so far indicate that the percentages of these released products were generally lower than the percentages reported in the NRC study.

In addition, the ORNL researchers found that the magnitude of the releases from the Zircaloy-clad fuel depends heavily on the extent of oxidation of cladding and fuel as controlled by the amount of steam available for reaction. Deposition characteristics of the released fission products in the thermal gradient tube and the filters indicate that cesium (Cs) and iodine (I) are present as CsI and other cesium-containing compounds and that silver, tellurium, and antimony probably occur in elemental form. Other source-term related programs at ORNL are investigating the chemical behavior of fission products after release from the fuel, their attachment to aerosol particles, and their transport through the reactor containment building.

ORNL's Plasma-Fueling Technique Helps MIT Achieve Fusion Firsts

As the lead laboratory within DOE for developing state-of-the-art devices for fueling fusion reactors, ORNL has been responsible for the latest advances in high-speed injection of supercold hydrogen pellets into superhot fusion plasmas (ionized hydrogen gas). This pioneering development has been based on two acceleration concepts: (1) a pneumatic, or gun-type, system and (2) an advanced mechanical injector based on a centrifuge principle. Cooperative experimental fueling programs are under way on three current fusion experiments—the Impurity Study Experiment (ISX-B) at ORNL, Alcator-C at Massachusetts Institute of Technology (MIT), and the Doublet-III device at General Atomic (GA) Technologies, Inc., in San Diego. The long-range goal is the development of practical systems for fueling a future fusion demonstration plant.

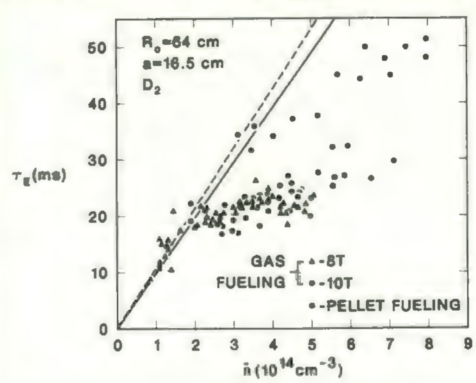


Standing at the Impurity Study Experiment (ISX-B) plasma-fueling setup are (from left) Dan Schuresko, Vernon Lunsford, Paul Lickliter, and Jim Peng.

The pneumatic injector is a gunlike device that shoots pellets of frozen hydrogen into the plasma of fusion reactors. Recently, the Massachusetts Institute of Technology (MIT) demonstrated that the plasma-fueling injectors modeled after ORNL's pneumatic injectors helped MIT's Alcator-C achieve two of the three limits (density, confinement time) required for break even (energy output equals energy input). Here, Stephen Combs adjusts ORNL's repeating pneumatic injector, a device that propels 3.5-mm deuterium pellets to a velocity of 1.5 km/s.

Recently, we have achieved pellet velocities as high as 1.5 km/s with the repeating pneumatic injector facility and steady-state pellet feed rates up to 40/s with the advanced mechanical injector. The latter device, which is now operational at a pellet velocity of 750 m/s, is scheduled to be used in the first demonstration of steady-state pellet fueling, on GA Technology's Doublet-III device.

However, the top achievement in plasma fueling this year—one that had major significance for the progress of the nation's magnetic fusion program—was the performance by ORNL's four-pellet pneumatic injector in a landmark experiment with Alcator-C at MIT. The device was the key ingredient in the first achievement of fusion "break even" conditions with respect to plasma density and confinement time. (Break even will occur when the product of the plasma density, confinement time, and temperature is high enough to ensure that the energy output of the device equals the input of energy needed to operate it.)



Pellet fueling at Alcator-C doubles the confinement time and increases the central plasma density.

In the MIT fusion milestone, the energy confinement time recorded in pellet-fueled discharges was nearly double that of the previous gas fueling. In addition, a much higher central plasma density was obtained—more than 10^{15} nuclei per cubic centimeter. The combined effect of these improvements, including a 50 ms confinement, is a Lawson product in the range of from 6×10^{13} s/cm^3 to 8×10^{13} s/cm^3, meeting the minimum conditions (except for temperature) for the achievement of fusion-energy break even.

As a result, ORNL-developed pellet fueling technology has become the new standard procedure for fueling advanced fusion devices. For example, an ORNL-designed pneumatic injector is being used on the Poloidal Divertor Experiment at the Princeton Plasma Physics Laboratory. The experimental successes provide a substantial boost toward meeting all of the break-even criteria by 1986–87 in the Tokamak Fusion Test Reactor at Princeton. The contributors to this key plasma-technology development are Stan Milora, Stephen Combs, Chris Foster, Wayne Houlberg, John Hogan, and Dan Schuresko of the Fusion Energy Division; Stan Attenberger of the Computer Sciences Division; and Vernon Lunsford of the Engineering Division.

Next: Milestones and Outlook

Milestones and Outlook

Architect's model of the High-Temperature Materials Laboratory. This facility will be built at ORNL by 1987.

Milestones—1983

From technical highlights we turn now to other important project and program milestones that marked 1983 as a year of great progress and accomplishment at the Laboratory.

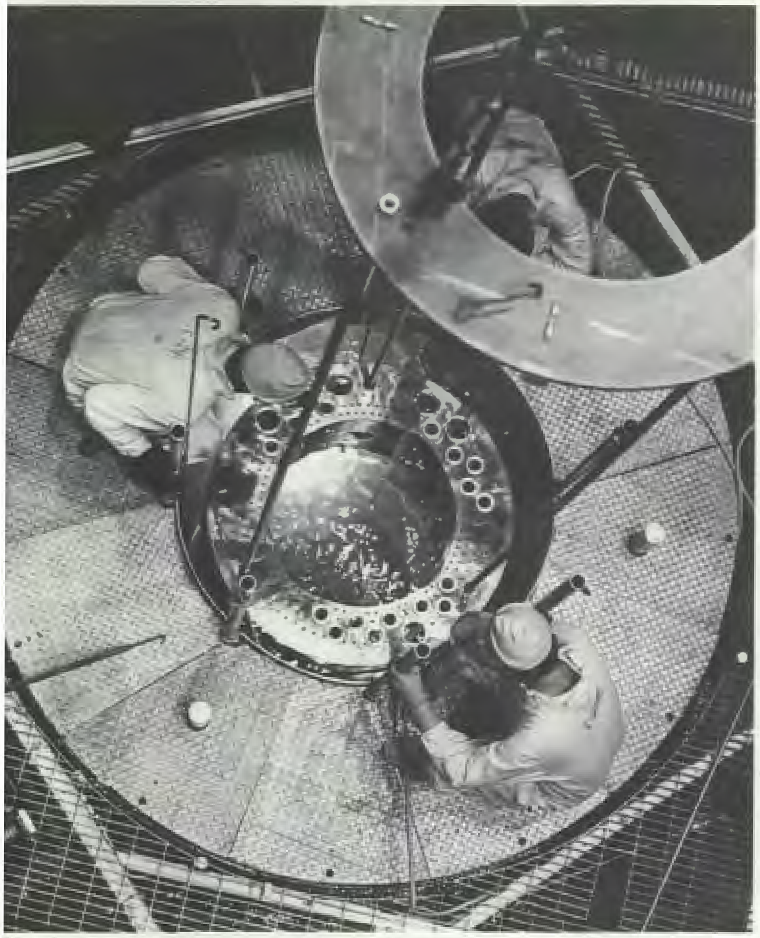
For the second year in a row, ORNL won **six of the I•R 100 awards** presented by *Industrial Research & Development* to recognize the year's 100 most important new-technology advances. This was the largest number received by any DOE or federal laboratory and equaled the highest for any organization in the competition. The awards bring the ORNL total to 37 (also the highest among DOE laboratories), 33 of which have been earned since 1976.

Also in 1983, five ORNL staff members were designated as **Union Carbide Corporate Fellows** in recognition of their continuing excellence in scientific or technological accomplishment. Those 5, bringing the total so honored at the Laboratory to 16 since the first in 1976, are Liane B. Russell, Charles D. Scott, John B. Storer, and Richard F. Wood as Corporate Research Fellows and Graydon D. Whitman as a Corporate Engineering Fellow.

New patent and consulting policies, recommended by ORNL and approved by DOE's Oak Ridge Operations in 1983, greatly improve the potential for new industry spin-offs from R&D at the Laboratory as well as this area's attractiveness as a site for high-technology development.

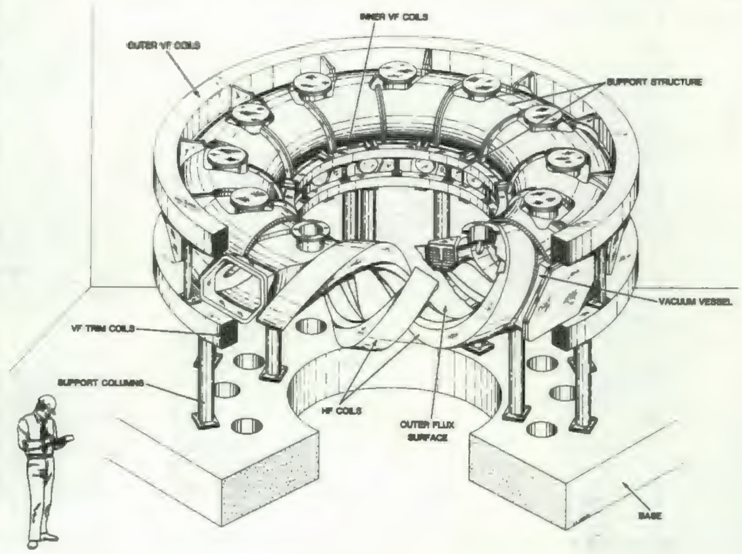
Two cooperative ventures also have strong implications for technology transfer and the creation of a university-industry-laboratory center of excellence in science and technology. The first is the **Distinguished Scientist Program** being established with the University of Tennessee; this program is designed to attract nationally renowned scientists to the Knoxville-Oak Ridge area as joint appointees of the University of Tennessee and ORNL. Another venture is the formal establishment of a **Research Institutions Consortium**, in which ORNL, DOE's Oak Ridge Operations, the University of Tennessee, and the Tennessee Valley Authority now are joined through a memorandum of understanding. The twofold purpose of this arrangement is to continue our cooperation on mutually beneficial programs and to identify and develop new ones.

Another cooperative effort, the user-oriented **High-Temperature Materials Laboratory**, reached a significant milestone this year when congressional appropriations reached $10 million of the estimated $20.6-million project cost.



The High-Flux Isotope Reactor (left) was shut down for three months in 1983 so that its beryllium reflector could be replaced. The new reflector, shown at right, reflects neutrons back into the core of the reactor.

Artist's conception of the Advanced Toroidal Facility (ATF), which will be operating in ORNL's Fusion Energy Division in 1986. The ATF offers improvements over the tokamak, the front-running fusion reactor concept, in its predicted capability to run steady-state, high-pressure plasmas.



A design has been approved and architect-engineering work is under way, moving toward the expected award of a construction contract early in 1985.

An important new element in DOE's magnetic fusion program, the $20-million **Advanced Toroidal Facility** (ATF) to be built at ORNL, was approved for construction. This optimized stellarator-type device, known as a torsatron, will replace the Impurity Study Experiment (ISX-B), whose successful program is to be completed this year. ATF, which will have more than twice the plasma volume of any other stellarator, will be the only large device of this type in the United States.

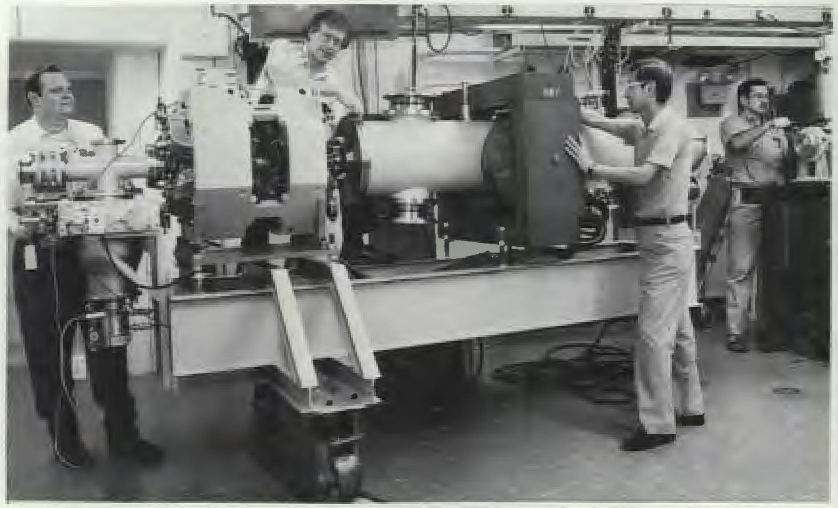
The torsatron concept offers features that could make it more appealing to utilities than the front-running tokamak. Unlike the pulsed tokamaks, it can operate without interruption. Because it does not have the plasma current found in tokamaks, it eliminates the plasma instabilities caused by the current. And it can achieve higher beta (ratio of plasma pressure to magnetic field pressure) than tokamaks, making it a potentially more economical source of power. These theoretical improvements of the torsatron over the tokamak concept will be investigated in the ATF. The product of an integrated physics and engineering design effort, it will investigate the "second stability region," in which—unlike the beta ranges currently accessible—higher beta values are coupled with greater plasma stability. Final design and component development for the ATF is in progress.

Under a five-year, $10-million agreement, signed in Tokyo in November 1983, ORNL and the Japan Atomic Energy Research Institute will collaborate on **tests of candidate structural alloys** for future fusion reactors. Both the High-Flux Isotope Reactor (HFIR) and the Oak Ridge Research Reactor will serve as high-intensity neutron irradiation sources to test which materials are the most resistant to radiation damage. The program will test both U.S.- and Japan-developed fusion "first wall" and blanket materials. The data will help to qualify alloys to be used in fusion engineering devices planned for the 1990s.

Another **new cooperative effort in fusion** involves Atlanta University, the graduate teaching and research component of the Atlanta University Center. Supporting President Reagan's Executive order on aid to historically black institutions, DOE's Office of Fusion Energy has provided funds for a range of cooperative activities involving

This tweezer-held capsule contains gadolinium-153, an ORNL-produced radioisotope now being widely used to help monitor the loss of calcium in the bones of aging people. The isotope helps doctors determine whether their patients need high-calcium diets, sodium fluoride treatments, or estrogen to combat calcium loss.

This velocity filter supplied by the Massachusetts Institute of Technology (MIT) is used to separate products of heavy-ion-induced reactions from the particles of the primary beam at the Holifield Heavy Ion Research Facility. Checking the facility are (from left) R. W. Miles, S. G. Steadman (MIT), H. J. Kim, and G. L. Sanders.



university faculty and graduate students and ORNL Fusion Energy and Computer Sciences staff and facilities.

In news about nuclear physics, for the first time the Holifield Heavy Ion Research Facility (HHIRF) achieved a **heavy-ion beam of 1 billion electron volts** (1000 MeV). Operating in a combined mode, HHIRF's two accelerators achieved that final energy when a beam of 160-MeV bromine ions from the new 25-MeV tandem electrostatic machine was injected into the Oak Ridge Isochronous Cyclotron, which boosts the energy of the beam.

A major **new on-line experimental device**, called a velocity filter, also took its place among the array of sophisticated detectors available for HHIRF users. The velocity filter, which was designed and built at the Massachusetts Institute of Technology, separates products of heavy-ion-induced reactions from primary-beam particles through velocity dispersion. The result is access to reaction products at a scattering angle near 0°, where most of the heavy particle flux in reactions of interest is concentrated. The filter was first used in July 1983 to measure the probability that nuclei will fuse near and below the Coulomb barrier (repulsive forces that come into play when particles having like charges approach each other).

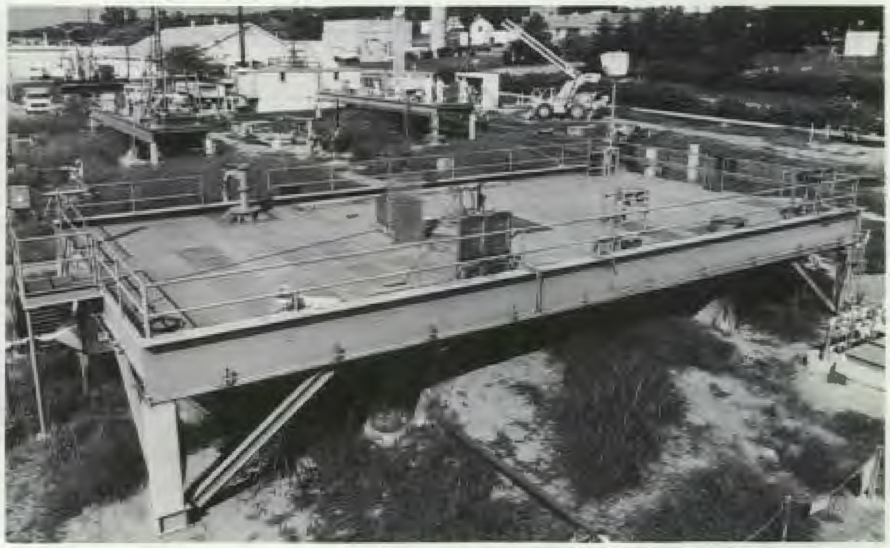
In 1983, after nearly eight years of service, the **beryllium neutron reflector** at HFIR was replaced in a three-month project carried out by members of the Operations Division. More than 120 special tools and fixtures were designed, built, and tested to perform the exacting manipulations required in a contaminated environment. The changeout, which had been done only once before in HFIR's operating history since 1966, represents a significant milestone in plant operation and maintenance.

In the **hydrofracture** project begun in 1982, ORNL has now permanently and safely disposed of the entire inventory of stored liquid radioactive wastes accumulated since 1943 in six gunite tanks located near the center of the X-10 complex. When the project began, the total volume of sludge remaining in the tanks was about 1.3 million L (350,000 gal), containing some 650,000 Ci of activity—predominantly strontium-90. The sludge has been resuspended in a bentonite slurry and pumped to the new Hydrofracture Facility for disposal in a series of 190,000-L (50,000-gal) injections.

An ORNL-produced radioisotope, **gadolinium-153**, is having a quiet but profound impact on nuclear medicine, with sales expected to approach $500,000 in

Because of broken, corroded pipes, radioactive substances are entering the sewage treatment plant at ORNL. As funding becomes available, efforts will be made to solve this environmental problem.

The sludge resuspension operation at the South Tank Farm. The sludge that settled from solution during the 37 years that the six gunite tanks were in use (1943–1980) was pumped to the new Hydrofracture Facility for permanent disposal.



1984. The isotope, which has a relatively long (241.6-d) half-life, is a key component in a bone-scanning device used to monitor bone mineral loss, which potentially affects 50 million people in the United States. Currently, because of aging, about 10 million people are suffering progressive calcium loss, which in its severe form is known as osteoporosis. By diagnosing the rate of calcium loss in a patient, a doctor can determine whether to prescribe a high-calcium diet, estrogen, or sodium fluoride to combat calcium losses and prevent bones from becoming brittle.

A Look Ahead

In the very near term, all of us will be interested and vitally concerned with the continuing process of transition to the new contractor, Martin Marietta. As I indicated earlier, the transition has taken shape as a stable, smooth transfer of operating responsibility from one corporate entity to another, with little impact on our programmatic tasks for DOE and other sponsors or on the bulk of our operations and procedures. What changes we experience will probably be felt very gradually, as Martin Marietta orients itself to the management tasks that lie ahead.

Under Martin Marietta's management, we can look forward to some new perspectives in selected areas, which reflect commitments the corporation made in its proposal to DOE. We can also expect initiatives that reflect Martin Marietta's experiences elsewhere and its evident desire to become a very active participant in the larger community in which we live and work.

One fundamental change in the DOE-contractor relationship relates to the terms of the new contract itself. For the first time for us—and for any of DOE's multiprogram national laboratories—an "award" fee will be paid to the contractor for its management of the facilities. This fee will not be a fixed, negotiated sum but rather one based in part on overall management performance as judged by DOE. This performance-based fee is designed to reward a contractor's initiative, efficiency, and effectiveness in both programmatic and administrative tasks. Admittedly, applying an incentive system is more difficult in endeavors involving primarily R&D, as at ORNL, than in endeavors that result in easily defined products and measures of accomplishment. Even so, I believe that the new system will support ORNL's traditional emphasis on the highest quality and creativity in R&D.

Another likely change is in the area of technology transfer. Here we anticipate that the many new tools now available to us—user facilities, patent waivers, exclusive licensing opportunities, and freer consulting arrangements—will greatly accelerate the spin-off of ideas into new industries. In its proposals to DOE, Martin Marietta has strongly committed itself to new initiatives in this area. We look forward to these initiatives, which can build on the excellent foundation we have already laid for more laboratory-industry interactions. We also look forward to the opportunity for ORNL-generated ideas and innovations to help stimulate the development of the Tennessee Technology Corridor, which will create for this area a broader base of high-technology industry.

The continuing upgrade of environmental-management systems and capabilities will be a major focus for the Laboratory in the years immediately ahead. A five-year plan has identified for priority attention three areas in which capital projects will be needed to keep ORNL in compliance with DOE requirements and other state and federal regulations governing environmental discharges. These areas are (1) the leaching of radionuclides from solid-waste disposal areas; (2) the need for pollution abatement and permit compliances, as in the case of our sewage treatment plant and coal-pile runoff; and (3) the handling and disposal of nonradioactive hazardous wastes, where implementation of both the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) during the last few years has imposed new, more stringent requirements. These problems require continuing research and operational attention to existing and expected standards, the current state of environmental control technology, and the effectiveness of available systems to meet ORNL needs. We also must consider in each instance various treatment options—for example, the costs and benefits of off-site disposal of hazardous wastes in lieu of on-site treatment and disposal. As always, we will use the best-available treatment technologies and operational practices as we strive to deal promptly and responsibly with the environmental impacts of our past, present, and future operations.

Conclusion

This annual report is an exciting opportunity for me to share with you both an overall perspective on the state of the Laboratory and specific examples of progress and individual and collective achievement. The quality of the accomplishments reported here testifies again, and as eloquently as possible, to the consistently high standards of performance applied to the professional challenges in all areas of our program and activity. This year my theme has emphasized work on many different scales, large and small, to help define the essential nature of our particular kind of scientific and technological institution. We respond to our mission and mandate, I believe, with exceptional intellectual vigor, creativity, and insight. The Laboratory truly represents an important national asset and resource—and a national trust for which all of us, as essential parts of the structure and fabric, bear a measure of the responsibility. That represents both an opportunity and a challenge, to which our staff members continue to respond with excellence and outstanding achievements. Finally, let me extend best wishes to the new members of the Martin Marietta team for continuing success in what really is a "Year of Transition." ornl

Members of the board of directors of Martin Marietta Corporation toured ORNL in February. Postma shows them the Surface Modification and Characterization Facility, directed by Woody White and Bill Appleton (standing behind Postma). Board members present are (from left) Bobby Leonard, Martin Marietta vice-president for personnel; Larry Adams, Martin Marietta president; Mary Jane La Barge, corporate secretary; Caleb Hurtt, president of Martin Marietta Aerospace; Ken Jarmolow, president of Martin Marietta Energy Systems, Inc.; and Albert Westwood, corporate director of research and development.

take a number

By V. R. R. Uppuluri

Numbers with Three Divisors

Look at any natural number with three divisors. For example, take 49 (with the divisors 1, 7, and 49) or 121 (with the divisors 1, 11, and 121). A list of all natural numbers that have exactly three divisors includes:

4, 9, 25, 49, 121, 169, 289, ...

It is interesting to note that the square roots of numbers in this list give the sequence of prime numbers:

2, 3, 5, 7, 11, 13, 17, ...

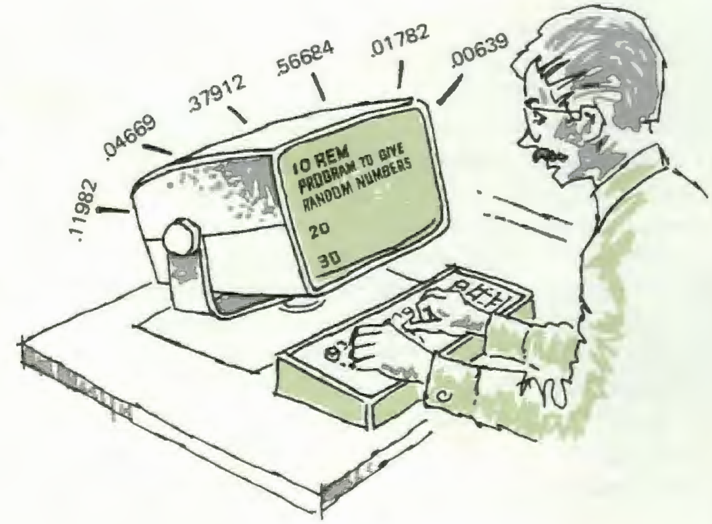
More on First Digits

Take two random numbers between 0 and 1 (such as 0.4 and 0.8). Divide the smaller number by the larger one (e.g., 0.4/0.8 = 0.5) and note the first significant digit (5 in this example). It can be shown that the first significant digit, either 1 or 2 or 3 or . . . 9, appears equally often; in other words, the probability that the first significant digit is equal to k (where $k = 1, 2, 3, \ldots 9$) is 1/9.

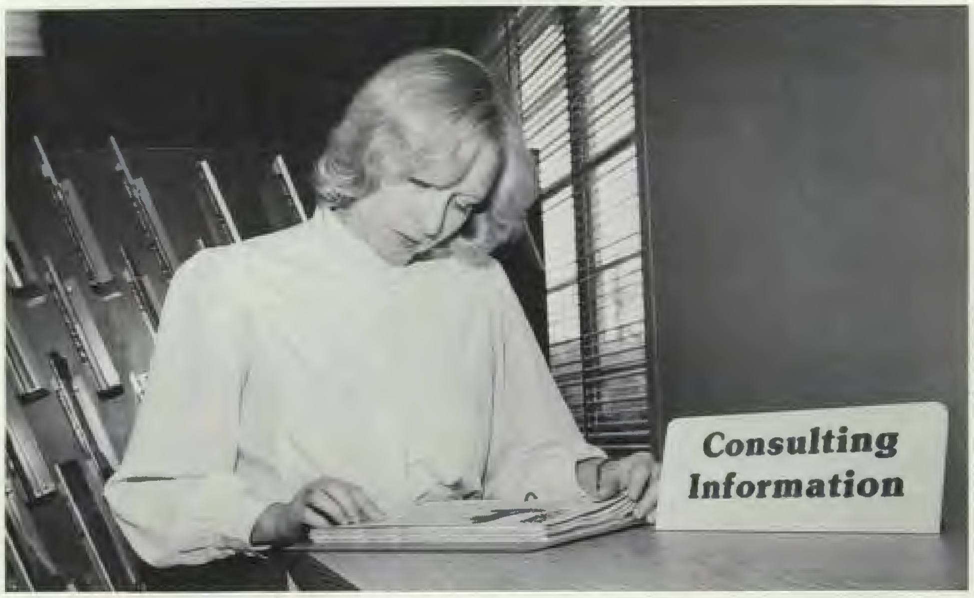
Suppose we divide the larger random number by the smaller one and note the first significant digit x. In the above example, $x = 0.8/0.4 = 2$. Then the probability (P) that the first significant digit is equal to k is

$$P[x = k] = 10/9k(k + 1), \quad k = 1, 2, \ldots 9.$$

The mathematical proofs of these results are given by Stephen H. Friedberg in the March 1984 issue of *College Mathematics.*



Fran Sharples works in ORNL's Program Planning and Analysis Office, where she manages the Laboratory's institutional planning process. She was responsible for the most recent issue of *Trends and Balances*, which informs the Laboratory staff of ORNL's future research plans. Last June she testified on the environmental implications of genetic engineering before two subcommittees of the Committee on Science and Technology of the U.S. House of Representatives. This year she was appointed to the Recombinant DNA Advisory Committee of the National Institutes of Health. She is a coauthor of the book *Biomass Energy Systems and the Environment*. A native of Brooklyn, New York, Sharples came to ORNL in 1978 after earning her Ph.D. in zoology from the University of California at Davis. Until October 1982 she worked in the Environmental Impacts Program of the Environmental Sciences Division, except for a few months in 1981 when she went to Washington, D.C., as an American Association for the Advancement of Science (AAAS)/Environmental Protection Agency Environmental Science and Engineering Fellow. In September 1984 she will depart ORNL again to serve as an AAAS Congressional Science and Engineering Fellow for a year in Washington. Her research interests include science and public policy, environmental aspects of energy technologies, applied ecology, and genetic engineering and its environmental implications. Here, she examines some consulting information in the Consultant's Corner in ORNL's Central Research Library.



Making R&D Pay Off:

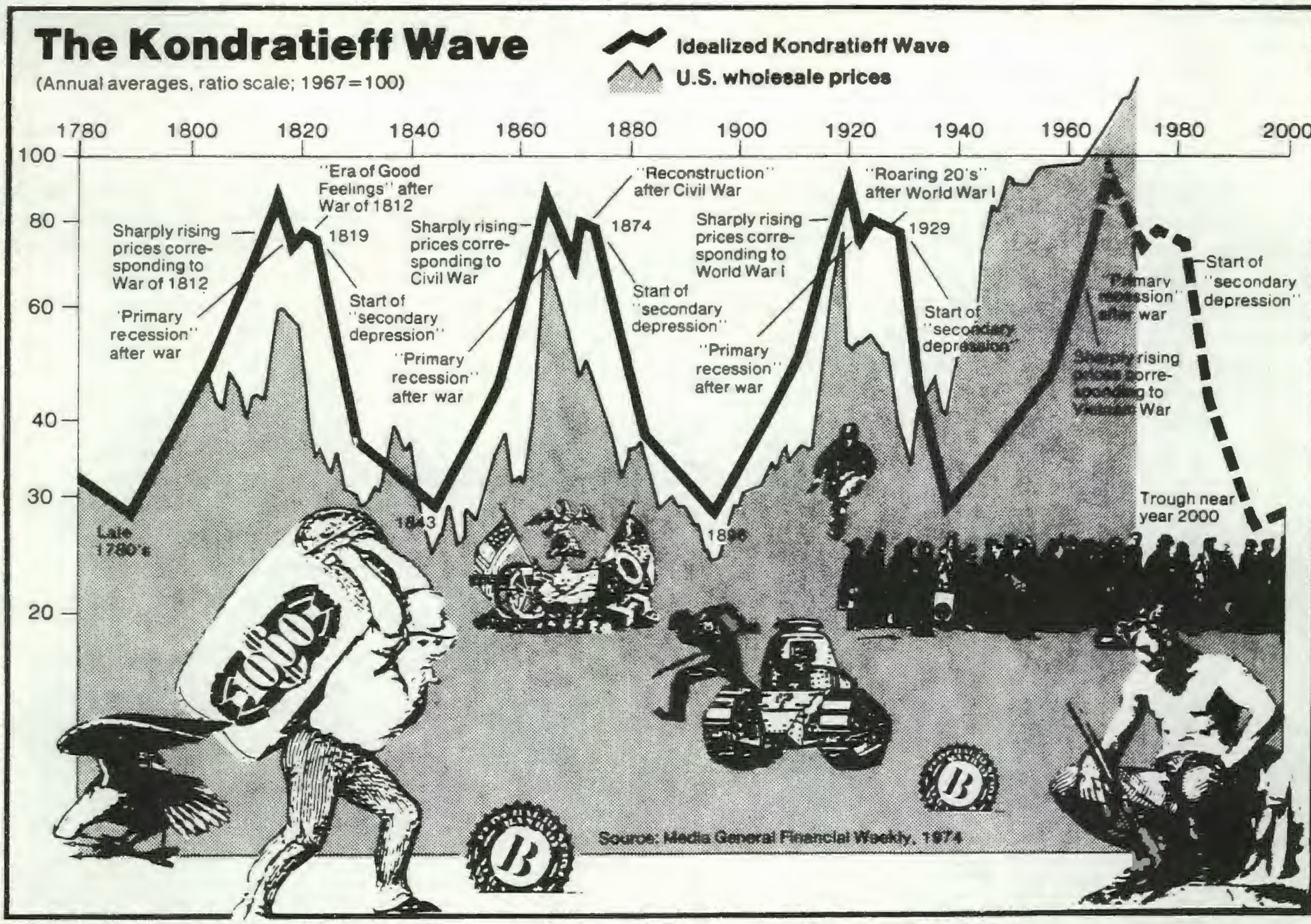
How ORNL Interacts with Industry

By FRAN SHARPLES

For most Americans the name Nikolai Kondratieff does not command instant recognition. Kondratieff, a Russian economist who once headed the Institute of Economic Research in Moscow, died in the 1930s in one of Stalin's prison camps. Despite his relative obscurity, however, a growing number of American economists are focusing their attention on a theory based largely on his ideas: the so-called "long-wave theory."

According to the long-wave theory, the world's industrial nations collectively experience regular cycles of economic growth and decline. A complete cycle lasts roughly 50 to 55 years: The first one began in the late 1780s and ended in the early 1840s, the second spanned a period from the early 1840s to the late 1890s, and the third ran from just before the turn of the century to the Depression of the 1930s. Although the theory is

Recently the federal government has removed impediments to the transfer of government-sponsored technology to industry. As a result, ORNL has new staff consulting and patent policies and has established a fund to promote technology transfer. Efforts also have been made by the federal government, Martin Marietta Energy Systems, Inc., and ORNL to stimulate and support the creation of small businesses to help the economy.



The Kondratieff Wave depicts the Russian economist's long-wave theory, which holds that the world's industrial nations collectively experience regular cycles of economic growth and decline. (Reprinted with permission from the New York Times.*)*

controversial (economists disagree on whether it is significant or even legitimate), it is of current interest because it offers a different perspective on the steep economic decline that virtually all of the world's industrial nations began to experience during the 1970s. The theory suggests that this decline may represent the downside of the fourth long wave and may eventually give rise to another upturn, or period of economic boom. It is easy to see why Kondratieff's ideas appeared heretical to traditional Marxists, who believed only in short-term business cycles and the long-term decline of capitalism.

Implications for Technology

What is perhaps most interesting about the theory is its implications for science and technology. Each long wave has tended to coincide with the waxing and waning of technological innovation, with the bust side of each cycle spawning a development of new technology, which in turn forms the basis of a new wave of economic expansion. These observations suggest that the process of economic recovery could be speeded up by increased government and corporate support for research and development (R&D).

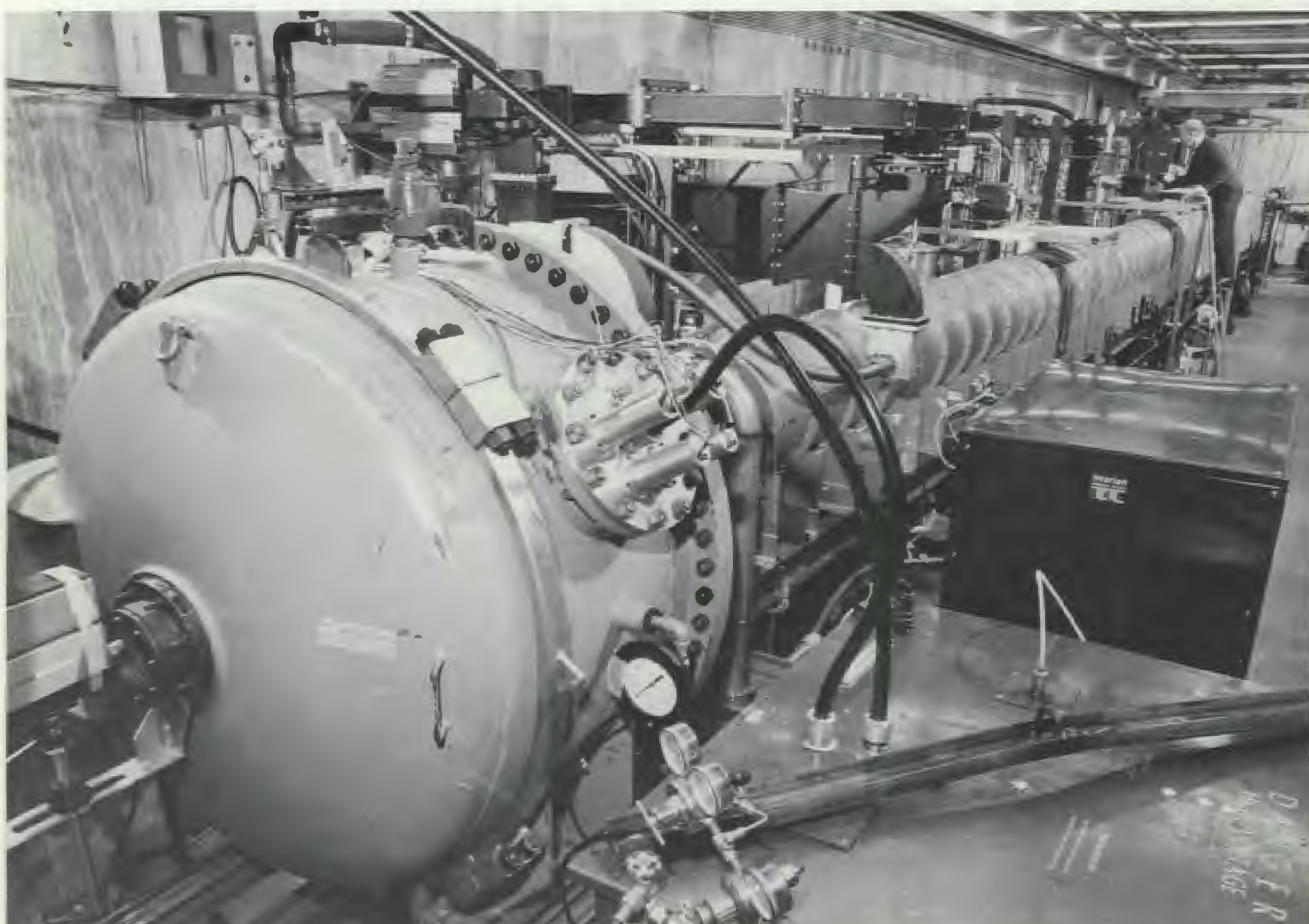
Although the hypothesis that depressions are responsible for surges in innovation is controversial, the United States is undeniably in the midst of a rising current of interest in revitalizing industry. A key concern of the corporate, government, and scientific communities alike is how to stimulate American industrial competitiveness. The answer coming from all directions seems to be this: by increasing technological innovation.

Technological innovation depends, in part, upon a successful system for performing R&D. But for R&D to have an economic impact, its results must be distributed to users in the form of cost-effective products and services. Without this transfer, the economy cannot benefit. While the United States has one of the world's most powerful and effective R&D performance systems, it is widely recognized that the results of much research are failing to penetrate the marketplace in the form of new commercial technology. Ralph Gomory, a vice-president and the director of research of IBM, recently put the problem very simply. It is hard, he said, to keep a simple idea secret; but it is even harder to give away "complex things." Technologies are complex things. If the receptors of research results do not know enough to generate the mass of detail required to apply the results, they can do very little with this new information.

Revitalizing Mechanisms

What will it take to better integrate R&D into the fabric of commerce? This is the question now being asked all over Washington but especially at the Department of Energy. The Stevenson-Wydler Technology Innovation Act of 1980 attempted to provide a framework of answers. Unfortunately, it was passed just before the change in federal administrations, which greatly dampened its effectiveness; and though the act emphasizes the development of a strong government-supported system for technology transfer, many of its provisions have not yet been implemented. Nevertheless, the Reagan Administration position on the issue is consistent with the Stevenson-Wydler Act—and even in a sense goes beyond it by providing needed policy underpinnings. Some of the elements of federal policy now emerging include the following:

Reaffirmation of support for basic research. The fiscal year 1984 federal budget, despite an overall climate of fiscal austerity, contained significant increases in funding for basic research. In addition, in response to the recommendations made by several scientific advisory panels that evaluated the national laboratories in 1982, stable *multiyear* funding is now



being proposed to provide the predictability required for continuity in long-term projects and planning for new facilities. In the private sector, too, more money is now being channeled into R&D. Spending on research projects in 1982 by 776 top U.S. companies climbed by 11.5% over 1981 R&D expenditures.

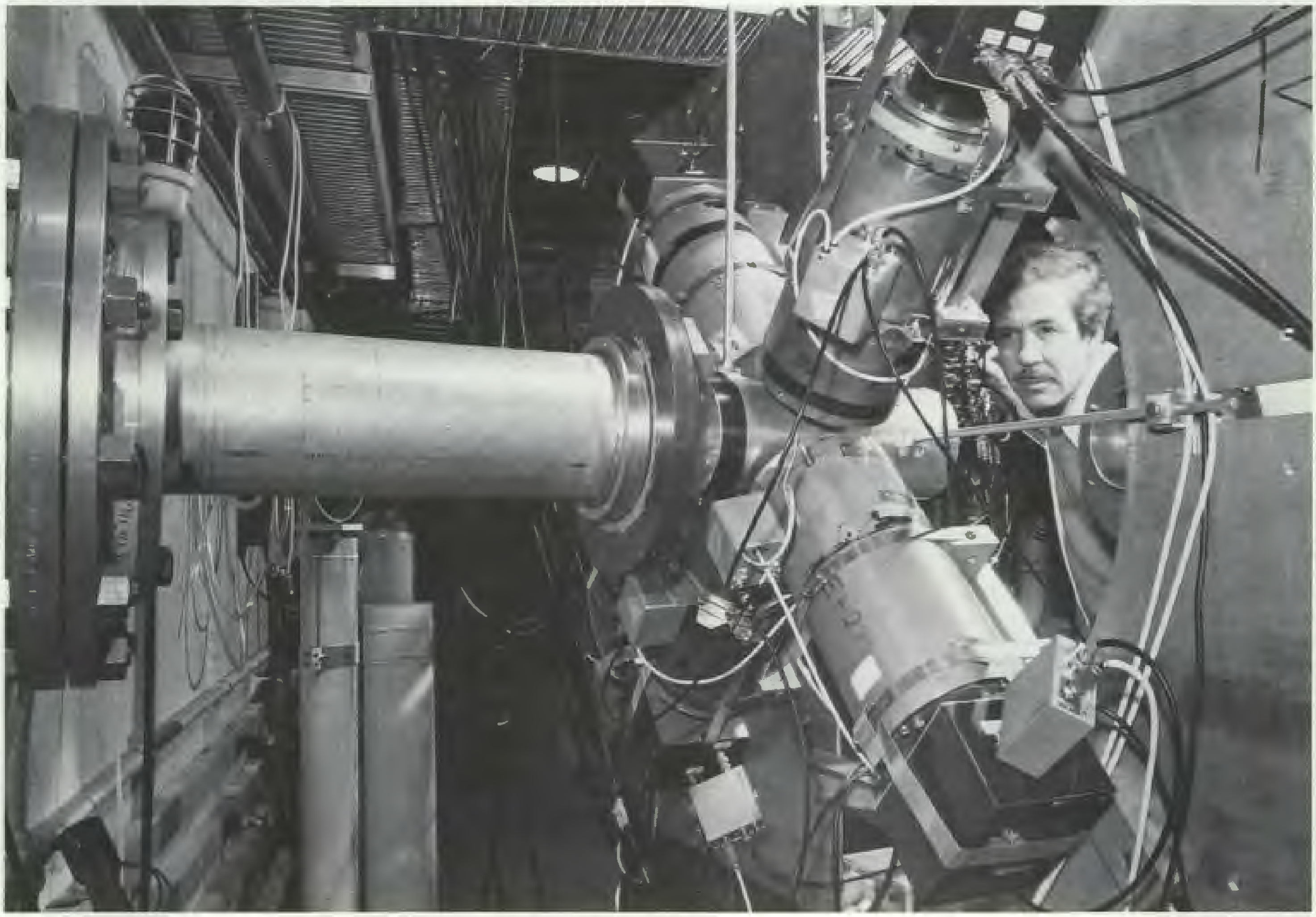
Increased emphasis on the importance of adequate funding and facilities for education. The American university system not only is a source of nationally important R&D but also is responsible for producing the future generation of skilled technical personnel. Both government and corporate entities are

ORNL User Facilities

User facilities are unique large facilities and equipment specifically designated by DOE for use by the technical community, including universities and industry. ORNL is currently the custodian of eight such facilities:

- Health Physics Research Reactor
- Holifield Heavy Ion Research Facility
- National Center for Small-Angle Scattering Research
- Neutron Scattering Facility
- Oak Ridge Electron Linear Accelerator
- Oak Ridge National Environmental Research Park
- Shared Research Equipment (SHaRE).
- Surface Modification and Characterization Facility

One of ORNL's user facilities is the Oak Ridge Electron Linear Accelerator (ORELA). The injector (left) produces electrons that are speeded up by the accelerator (center). The accelerated electrons bombard a tantalum target in an evacuated room (far right), thus producing neutrons used for experiments and cross-section measurements. The photograph at right shows a special detector used at ORELA for simultaneous measurements of both capture and fission in heavy nuclides important for nuclear reactor applications.



How ORNL Can Stimulate the Economy

Small business is the cornerstone of today's economy. A recent study conducted at the Massachusetts Institute of Technology found that between 1969 and 1976, small firms that employ 20 or fewer people created two-thirds of the nation's new jobs. Many of these small companies were started by inventors and entrepreneurs. In addition to stimulating the economy by providing jobs, these firms have increased the nation's productivity and contributed new ideas and products. According to Larry Udell, president of the National Congress of Inventor Organizations (NCIO), for each dollar spent on research and development, small companies produced up to 24 times as many innovations as large corporations.

To help spur innovation and economic growth, the federal government is providing support to inventors, prospective entrepreneurs, and small businesses. One example of support is the Energy-Related Inventions Program (ERIP) of the U.S. Department of Energy. The program, which has existed since 1975, provides support to independent inventors and small businesses to help move their promising energy-related inventions closer to the marketplace. How effective has this program been in creating jobs?

According to an evaluation of ERIP conducted by Jon Soderstrom and Lois Bronfman of ORNL's Energy Division and Marcia Rorke of Mohawk Research Corporation, from 1975 to 1983 DOE has awarded grants totaling $12.8 million for 165 of the 208 inventions recommended by the National Bureau of Standards, which was directed to evaluate the inventions and advise DOE of those found to be promising. "Of these inventions," they reported in September 1983, "35 have reached the marketplace, and their cumulative sales to date total $178 million. An additional 10 inventions are now starting into production. Jobs that have been created directly by production related to the inventions total 756." That's one job for every $17,000 of federal funds expended for ERIP grants.

ORNL's evaluation shows that DOE's investment not only created jobs but also did so at a success rate equivalent to that of many private venture capital firms. And the leverage ratio—ratio of the investment to the sales figures—was 17.5:1, which compares very favorably with the 10:1 ratio of the National Science Foundation's Small Business Innovation Research Program and the Department of Commerce's Technology Commercialization Centers.

At ORNL there is a new impetus to facilitate the transfer of technology developed at the Laboratory to established industries or to new firms, including those started by ORNL staff members with the entrepreneurial spirit. This impetus springs from two sources: a commitment by the state to attract high-technology businesses to the nearby Tennessee Technology Corridor and the liberalized DOE consulting and patent policies. ORNL employees are now encouraged to offer technical advice to businesses or to form new companies that market technologies developed at ORNL. Herman Postma, ORNL director, is credited with bringing about the policy change.

The change reflects a turnabout in attitude. According to David Patterson of the Tennessee Technology Foundation, the three scientists from ORNL who in the late 1950s founded ORTEC (a nuclear instrumentation company that now employs 450 people) were criticized for "stealing ORNL technology and making a profit from it." This attitude has changed remarkably since Postma became Laboratory director in 1974. In 1975 when Bert Ackermann, then an ORNL employee, decided to start Technology for Energy Corporation (which now employs 290 people), ORNL gave him support. For three years, Ackermann's firm was identified by *Inc.* as one of the 500 fastest growing companies in the United States.

Says Postma: "There are now between 50 and 60 spin-off firms in the Oak Ridge–Knoxville area that market technological innovations. Half of these firms started up in the last 4 years." He adds that employees can take the risks of launching businesses and still receive their salaries.

One indication of the Laboratory's commitment to stimulate the local economy was its cosponsorship of a series of seminars to teach employees how to become entrepreneurs. Called "Building a Technology Business: From Invention to Private Enterprise," the seminar series was held December 3–9, 1983, in Oak Ridge and Knoxville during Technology Transfer Awareness Week.

ORNL employees who attended the seminars heard Ed Young, vice-president of NCIO, say that inventors often make the mistake of creating devices for which there is no need. He suggests that inventors determine what the market demand is and then create a product that meets that demand. A similar point was made by Al Shapero, professor at Ohio State University. He said that market pull works better than technology push, that inventions should rise to meet market demand.

In his talk about inventors and entrepreneurs, Shapero said, "Inventors are driven by the desire to create an

This engineering prototype of Technology for Energy Corporation's (TEC's) new Model 1610 Mobile X-Ray Stress Analysis System is an example of technology transfer from ORNL and Northwestern University. This system is equipped with a portable X-ray diffractometer mounted on the end of an articulated arm, a position-sensitive X-ray detector (developed at ORNL by Manfred Kopp and Cas Borkowski), and a DEC LSI 11/23 computer-based data acquisition system. It is used to measure nondestructively residual and loading stresses in metal components in the factory or field. The key to the system is the Kopp-Borkowski detector. Bob Hendricks, formerly of ORNL, is marketing the system for TEC.

invention that is useful, and entrepreneurs are driven by the desire to be independent. Money is a secondary motivation."

ORNL's new contractor, Martin Marietta Energy Systems, Inc., has promised to administer an aggressive technology transfer program. According to the community-development part of its contract proposal, Martin Marietta will invest 10% of its annual contract-management fee as venture capital to support fledgling firms and spin-off industries, particularly those that market products and technologies developed at DOE plants, including ORNL. Bill Carpenter, vice-president for technology application, is in charge of technology transfer. Says Carpenter, "I will seek the commercial utilization of all suitable innovations at the plants and will support entrepreneurial efforts, particularly in the Oak Ridge community." On May 10, 1984, Energy Systems announced that it had agreed to invest about $1 million in Maxima Corporation in Oak Ridge in return for 18% of the company's stock and two seats on its board of directors.

Ken Jarmolow, Energy Systems president, says that Martin Marietta has proposed a method for expediting the cumbersome process of transferring technology from government control to the private sector. Currently, patent rights to innovations made at ORNL (except for proprietary research by industrial scientists at ORNL user facilities) are initially owned by the federal government (DOE). Martin Marietta proposes that DOE (1) waive its rights to technologies developed at ORNL (and Energy Systems' other government plants) and (2) give the company the authority to review requests from interested firms and entrepreneurs and to license or transfer the technology to the appropriate enterprises. It is also proposed that any returned revenues be rededicated to further transfer initiatives, such as developing products or processes with commercial promise to a state where industry can realistically assess their potential.

A step forward in transferring patent rights from government to industry was made in an unusual contract signed March 28, 1984, by the presidents of Cabot Corporation (a Boston-based company, with a local office in Oak Ridge) and Union Carbide Corporation's Nuclear Division. (The contract has since been taken over by Martin Marietta.) In this materials-science partnership, Cabot is supporting work by ORNL researchers and has sent one of its electron microscopists to ORNL to conduct research in the area of long-range-ordered alloys. Hani Tawancy, the Cabot scientist, is working with C. T. Liu of ORNL's Metals and Ceramics Division on improving the ductility of alloys of interest to Cabot—namely, a nickel-molybdenum alloy and a series of nickel-silicon alloys (brittle materials that are resistant to corrosion in a highly acidic environment). Under the contract, if Cabot and ORNL researchers make any innovations at the Laboratory in these alloy systems, Cabot can retain patent rights to the innovations—a breakthrough in government-industry relationships on the patent issue.

Yankee ingenuity is making a comeback, thanks to the prolific sprouting of small businesses and the nurturing of inventors and entrepreneurs by the federal government. East Tennessee ingenuity, new liberalized government policies, and the technology-transfer commitment of Martin Marietta could turn the proposed Technology Corridor into a rich garden of technology-based businesses that will nourish the economy.—*Carolyn Krause.*

now stepping up support for university education and research, while deficiencies in science and mathematics education at the secondary level are receiving more attention than they have for years.

Providing encouragement for, and removing impediments to, transfer of government-sponsored technology to industry. A variety of changes in government policy have been made to facilitate more cooperative activities between industry and federal R&D institutions. For example, DOE's nine multiprogram national laboratories are stewards of some of the most advanced scientific research equipment in the world. Facilities like the National Synchrotron Light Source at Brookhaven National Laboratory and the High Flux Isotope Reactor (HFIR) here at Oak Ridge National Laboratory represent research resources so costly that they could virtually never be duplicated by industry. Until recently, however, any private firm's need to keep research results out of the hands of its competitors ran up against a major stumbling block: the government requirement that federally subsidized research be published openly. The regulations have now been changed so that companies can conduct proprietary research at the DOE laboratories if they pay for the use of the experimental facilities. This change has led to increased activity by industry at many of the DOE laboratory "user facilities" (see box on p. 35).

Another problem that has traditionally discouraged industry from greater involvement with the federal laboratories is patent policy. The patent system, which is as old as the U.S. Constitution, has historically provided an incentive to innovate by rewarding individual inventors with the right to effectively maintain a monopoly on resulting commercial products. In recent years, however, the government has been entitled to claim patents on all inventions made as a result of work done at federal facilities, even if the work is sponsored by industry. Such an arrangement effectively deters industry from using federal R&D resources.

Therefore, in 1983 DOE began to greatly expand the use of its statutory authority to waive its rights and thereby allow contractors working at federal facilities to retain rights to their inventions. President Reagan issued a new patent policy more favorable to industry, and Congress passed new legislation (the Bayh-Dole Act) to allow small business firms and nonprofit organizations to retain rights to their inventions. As these changes become widely known and understood, they should encourage companies and nonprofit groups of all sizes to use federal research facilities.

Technology Transfer at ORNL

Technology transfer is nothing new at ORNL; the Laboratory has had some form of industrial cooperation program since 1962. Currently, our technology-transfer activities are administered through the central Office of Research and Technology Applications (ORTA). As a result of a recent administrative change, Don Jared, former director of the office, now reports to W. W. (Bill) Carpenter, vice-president for Technology Applications and head of the newly-established Office of Technology Applications for Martin Marietta Energy Systems, Inc. Jared is manager of technology assessment in the new Energy Systems office, and Mel Koons, who also reports to Carpenter, is manager of licensing and business evaluations. Jared's replacement as ORTA director is Jon Soderstrom of the Energy Division, who now reports to Raymond Wiltshire, ORNL's executive director for Support and Services. At ORNL technology-transfer activities are coordinated through 21 part-time division and program technology transfer officers. Funding for ORTA comes from overhead ("taxes" paid by the research divisions to support Laboratory services), but individual Laboratory programs pay for much of their related technology-transfer activities.

Although ORNL's past efforts in technology transfer have been highly successful (see the Fall 1978 *Review*), problems have always existed that we could not solve. Funding for ORTA, for example, has been adequate to disseminate information only by written reports and through workshops. While open access to research results through all the usual channels—journals, technical manuals, information centers, conferences, and so on—is vital, it is not the best way to get the results to industry in a form it can use. The viewpoint of industrial users of research results has been expressed succinctly in a recent paper by Donald W. Collier, a senior vice-president of the Borg-Warner Corporation. Writes Collier, "The best technology transfer agent for commercialization of an invention is the group of people who developed the technology. The worst is a research report. . . . It is virtually impossible to incorporate everything that the R&D people have absorbed through their pores in a research report, and if it were, nobody would read it."

People-to-people interactions are a much more productive avenue for technology transfer than mere publication and dissemination of results. Unfortunately barriers to such interactions have existed for a long time. For example, until recently, ORNL researchers were virtually forbidden by DOE regulations to act as paid consultants to industry, and industry was discouraged from coming to ORNL by the restrictions on proprietary information and patents. Happily, the situation is changing. DOE has now agreed that, for the purpose of technology transfer, ORNL personnel may consult on their own time for American-owned and U.S.-based firms. Of course, consulting will be allowed only as long as no conflict of interest exists and no internal abuses occur (a committee of ORNL staff members has developed a code of ethical standards for consulting). The level set for fees that may be accepted is generous enough to provide employees an incentive to become consultants. Interested employees may now take advantage of the new Consultant's Corner in the ORNL library, where general information on consulting is available. An in-house seminar on consulting is also planned, possibly for the Fall/Winter Management Resource Development Program.

In addition to changing the rules that once made participation at user facilities unattractive to industry, ORNL plans to make a greater effort to promote increased use of these facilities through expanded publicity on what is available to industry. In the past, promotional material has not always made clear what the practical applications of our very sophisticated equipment might be. Efforts are being made to correct this situation.

Perhaps the Laboratory's most important new approach to more aggressive technology transfer involves the establishment of a new pool of funds to support the actual transfer of equipment and materials to industry for testing preliminary to possible product development. In the past, a gap has existed between the development of a new material or instrument here at ORNL and the production of an actual commercial product. For example, new alloys with improved properties are developed at ORNL regularly. But the superior qualities of a new material can be demonstrated on only minute amounts at the laboratory bench, and such test results are generally not sufficient justification for major industrial investment in further development even when commercial potential is high. Appropriate applications must be identified, and large enough quantities of a new material must be produced for testing under more realistic conditions, before a promising new material can attract commercial interest. Unfortunately no funds for producing adequate test quantities of new materials have generally been available. Similarly, the invention of a novel or improved instrument usually means that a new one-of-a-kind piece of equipment is available for use only at ORNL. Yet to attract commercial interest, a duplicate instrument that can be given to industry for evaluation is almost essential, especially if the instrument is highly complex. No funds have previously been available to produce duplicate instruments.

Last year, ORNL's Executive Committee decided to establish a fund to provide support for getting new developments over these initial humps. We are setting aside a much larger sum of money to be devoted specifically to technology-transfer efforts than ever before, and we have asked DOE to match this amount. So far, DOE has approved $100,000 for this purpose, and ORNL is providing an equal amount this year. In addition, an internal screening committee was established to identify and select for increased support the ORNL inventions with the greatest commercial promise. On April 26, 1984, the committee began accepting proposals from staff members seeking to use part of the $200,000 fund for further developmental work on products or processes to increase their commercial potential. Projects selected to receive grants from the Technology Transfer Fund include nickel aluminide alloys, a pulsed helium ionization detector for gas chromatography, multicomponent separations by continuous chromatography, electronic autofluorography, and remote analytical instrumentation.

Martin Marietta Energy Systems, Inc., has begun to make specific plans for technology transfer. The establishment and staffing of the new Office of Technology Applications is an example. In establishing this office, Ken Jarmolow, Energy Systems president, wrote that the office is responsible for meeting "the company's significant commitments regarding technology transfer and local economic development" and for "implementation of a centrally directed program that ensures timely and effective use of intellectual properties and technologies developed throughout the company." Jarmolow believes that, through the work of the new office, Energy Systems has the "potential for dramatic success" in technology transfer. From what was stated in the community development part of the contract-management proposal, it is obvious that ORNL's new contractor is very serious about the subject. Martin Marietta has a strong grounding in technology transfer from its work for the National Aeronautics and Space Administration; in fact, the company's understanding of technology transfer was one reason for its selection as contractor. So, we can expect the emphasis on technology transfer to grow in the future. And if Kondratieff's theory has any validity, our technology-transfer efforts may help spur the economic growth needed to help the nation climb up the next long wave. ornl

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CORRECTION

The ORNL *Review* regrets an error of omission made in the Number One 1984 issue. The cover caption failed to mention that Tom Swift, a University of Tennessee student in electrical engineering, is the man playing checkers with the one-armed robot.

BOOKS

Betrayers of the Truth,
William Broad and Nicholas Wade, Simon & Schuster, New York (1982), 256 pp. Reviewed by William S. Lyon, Analytical Chemistry Division.

Most humans consider themselves highly moral. From the ancient days when the Pharisee prayed in the temple, "God, I thank thee that I am not as other men are, extortioners, unjust, adulterers," to several years ago when a U.S. President solemnly told a nationwide television audience, "I am not a crook," human nature has changed very little. This sense of self-righteousness allows us to excuse our own misdeeds even though we would condemn such acts if done by others. Hence, it is not surprising that in 1981 Phil Handler, president of the National Academy of Sciences, testified before a congressional committee that scientific fraud is a "grossly exaggerated" problem.

In this well-researched book, however, Broad and Wade document quite a few instances of scientific fraud, including that perpetrated by illustrious scientists such as Galileo, Darwin, Mendel, and Millikan. For example, they include the saga of the Piltdown man, the most famous scientific hoax. In 1908 amateur geologist Charles Dawson, in collaboration with Arthur Woodward of the British Museum, discovered bones in a gravel pit and pronounced them as the "missing link." Convinced that the bones were fraudulent—a recent book suggests that Sir Arthur Conan Doyle, creator of Sherlock Holmes, planted them—Martin Hinton, a zoologist at the British Museum, buried some obviously faked fossils in the Piltdown pit. Hinton expected his hoax to be recognized and thus bring into question the entire Piltdown episode. To his surprise the faked fossils were accepted as real, including an elephant bone carefully carved to resemble a cricket bat! In the 1920s Piltdown began to be suspect, but not until the 1950s were dating techniques sufficiently refined to uncover the hoax.

The authors also mention a number of other more recent data doctorers, figure fudgers, and experiment falsifiers, most of whom they have previously discussed in *Science* articles. For example, they recount the story of William Summerlin, who painted black spots on white mice to make his research on the immune system look good.

By concentrating on these serious breaches of ethics, Broad and Wade paint a pretty dismal picture of the scientific establishment and its methods of checks and balances. Peer review, duplication of experiment, and the entire institutionalized process of big science get poor marks. While statistically the authors have a rather insignificant sample, politically the sample makeup creates lots of noise.

Because of its compelling narratives about the fraudulent practices of past and present scientists, *Betrayers of the Truth* makes absorbing reading. However, the book is also interesting because it does more than recount sins; it delves into the psychological and philosophical nature of science. Consider, for example, the authors' perception of the scientific method, as discussed in the last chapter. "Science," they write, "is first and foremost a social process; the researcher who discovers the secret of the universe and keeps it to himself has not contributed to science. Secondly, it is a historical process: it moves forward with time, it is an integral part of civilization and history . . . . Thirdly, science is the cultural form that allows fullest opportunity for the expression of human propensity for rational thought."

However, as the authors point out, the rational component is not the only element of science; ambition, envy, and deception also play a role—to the surprise of many. Because science has virtually replaced religion as the fount of all truth, scientists are often perceived as embodiments of virtue. They are not. Scientists are human and may bend under excessive pressures, including the "publish or perish" edict, the struggle for tenure, the search for funding by writing proposals, and the desire to win prizes or be the first credited with making a discovery.

Broad and Wade offer several suggestions for reducing these influences, for example, cutting back the number of journals and eliminating second-rate science. Most of these ideas we have heard before. Some of the authors' proposed solutions, such as counting citations to evaluate scientific worth objectively, are as idealistic as the purist's view of science. (They forget that bad research is cited by competent scientists who have disproved the results of the shoddy work.)

Scientific dishonesty tars all of us with its brush. However, it seems to occur with greater frequency in certain disciplines and institutions. At Oak Ridge National Laboratory, we have so far escaped major scandal. Many of us are aware of minor peccadillos such as reworked data and discarded outliers, but, for the most part, our research results have withstood the test of time. Because the Laboratory's emphasis historically has been mainly physical science of a type that can be verified by others, we have not suffered the embarrassments of some medical institutions, where confirmations are often either unattempted or blurred by psychological factors.

After reading the consequences of shoddy or outright dishonest laboratory practices as documented in *Betrayers of the Truth*, all of us should make a renewed commitment to scientific integrity. Failure of an experiment is trivial compared with failure of honor—the ultimate message in the book. ornl

BOOKS IN PRINT

The following books in print were edited primarily by ORNL staff members.

Groundwater Pollution: Environmental and Legal Problems, proceedings from the annual meeting of the American Association for the Advancement of Science (January 7, 1982, Washington D.C.), ed. Curtis Travis and Elizabeth Etnier, Westview Press, Boulder, Colorado (1984).

Statistical Methods and the Improvement of Data Quality, Proceedings of the Small Conference on Improvement of the Quality of Data Collected by Data Collection Systems cosponsored by ORNL and the Office of Naval Research (November 11-12, 1982, Oak Ridge), ed. Tommy Wright, Academic Press, New York (1983).

Radionuclide Generators: New Systems for Nuclear Medicine Applications, proceedings from the symposium sponsored by the Division of Nuclear Chemistry and Technology at the 185th meeting of the American Chemical Society (March 20-25, 1983, Seattle), ed. Furn F. Knapp, Jr., and Thomas A. Butler, American Chemical Society, Washington, D.C. (1984).

Physics of Electronic and Atomic Collisions, invited papers from the International Conference on the Physics of Electronic and Atomic Collisions (July 1981, Gatlinburg), ed. Sheldon Datz, North Holland Publishing Company, Amsterdam (1982).

Room-Temperature Phosphorimetry for Chemical Analysis, ed. Tuan Vo-Dinh, John Wiley Interscience, New York (1984).

Fast Ionic Transport in Solids, proceedings of the International Conference on Fast Ionic Transport in Solids (May 18-22, 1981, Gatlinburg), ed. John B. Bates and G. C. Farrington (University of Pennsylvania), North Holland Publishing Company, Amsterdam (1981).

Trends in Welding Research in the United States, proceedings of a conference of the American Society for Metals (November 16-18, 1981, New Orleans), ed. S. A. David, American Society of Metals, Metals Park, Ohio (1982).

Grain Refinement in Castings and Welds, proceedings of a symposium of the Metallurgical Society (October 25-26, 1982, St. Louis), ed. G. J. Abbaschian (University of Florida) and S. A. David, Metallurgical Society, American Institute of Metallurgical Engineering, Warrendale, Pennsylvania (1983).

Analytical Spectroscopy, proceedings of the 26th Conference on Analytical Chemistry in Energy Technology (October 11-13, 1983, Knoxville), ed. William S. Lyon, Elsevier Science Publishers, Amsterdam (1984).

Transportation Energy Data Book (6th ed.), ed. Gretchen Kulp and Mary C. Holcomb, Noyes Data Corporation, Park Ridge, New Jersey (1983).

Alternate Nuclear Waste Forms and Interactions in Geologic Media, proceedings of a workshop cosponsored by ORNL and the Division of Materials Sciences, Office of Energy Research, U.S. Department of Energy (May 13-15, 1980, Gatlinburg), ed. Lynn A. Boatner and George C. Battle, Jr., DOE, Washington, D.C. (1981).

Carl Goldstein

Dick Smyser

Betty Anderson

Chauncey Starr

Panelists in Institute for Energy Analysis conference room.

Communicating Health Risks to the Public

By CAROLYN KRAUSE

The American people have become a society of "healthy hypochondriacs," according to Lewis Thomas, president emeritus of Memorial Sloan-Kettering Cancer Center. Although we are healthier and our lives are safer than ever before, we still worry about the risks to our health from environmental agents like radiation, air pollutants, and industrial and agricultural chemicals. Many Americans are convinced that we are in the throes of a cancer epidemic that is caused by exposure to environmental agents typical of an industrial society.

These fears are not completely justified. Statistics show that one of five Americans dies of cancer and that diet and smoking account for a larger percentage of cancers than does the environment. Furthermore, the overall cancer incidence has not increased in recent years; in fact, for some major cancers, such as bowel cancer, the incidence is decreasing. The only major cancer whose occurrence is increasing is lung cancer, and this increase is almost certainly caused by smoking, not environmental effects.

So, why are we worried? Why does the public's perception of risk appear to be different from the actual health risks of certain environmental agents? The sources of this public anxiety are primarily the scientific establishment; the news media; and culturally influenced fears, beliefs, expectations, and values. That was the consensus of a February 24, 1984, workshop held in Oak Ridge.

The workshop, "Communicating Risk: Science, Media, and the Public," was sponsored by the East Tennessee Chapter of the Society for Risk Analysis. Many of the chapter's members—including the chapter's current president, V. R. R. Uppuluri—are from Oak Ridge National Laboratory. Some of the ORNL members served on the steering group that guided the formation of the international society and founded its journal *Risk Analysis* (which is edited by Curtis Travis of ORNL).

Chauncey Starr, the father of risk analysis and vice-chairman of the Electric Power Research Institute, told workshop participants that "it is impossible for science to prove the absolute safety" of any product or technology because too many unknowns exist. This principle, he added, causes anxiety.

Starr said that most of the ill effects that scientists know about result from very high measurable levels of exposure. An example of a

Ed Aebischer, ORNL, moderator.

Starr, EPRI, keynote speaker.

Goldstein, U. S. Committee for Energy Awareness

Smyser, president, American Society of Newspaper Editors

measurable effect is the bladder cancer caused in rats by exposure to high doses of the artificial sweetener saccharin. On the other hand, Starr notes, the risk to humans of low doses of saccharin is a hypothetically extrapolated one—that is, scientists are not very certain there is a risk.

Scientists run into problems when they try to calculate the health effects of low levels of exposure based on the observed effects at the much higher exposures used in animal experiments. "Projections represent professional estimates of what will probably occur at low levels," Starr said. "Projections to low levels are speculative, judgmental, and not necessarily right. Science is not deterministic, but probabilistic."

Although scientists think in terms of probabilities and estimates, Starr argues that most members of the public, including legislators, want answers couched in terms of certainties and cause-and-effect relationships. Their "illusion" of the world is based on perceptions, and these perceptions may treat a probability as a sure sign of danger. Thus public policies and proposed actions are based on estimates that harmful effects at low levels of exposure will occur. The proposed ban of saccharin in food and drinks is an example.

The ban on the use of the tranquilizer thalidomide resulted partly from a perception that a real risk to humans existed. The thalidomide tragedy in the 1960s, when many pregnant German women who took the tranquilizer bore horribly deformed children, did not affect Americans on the same scale because the drug was still being tested in the United States when the problem in Germany became apparent. The tests were the result of a government policy that calls for measurements of the effects in animals of exposure to high levels of new drugs. The policy also calls for banning the sale of drugs if there is reason to believe that low-level effects in humans may be harmful.

Public policies, says Starr, are based on illusions that certain agents jeopardize our health and that certain actions contribute to it. "We have the illusion that if we live right and get proper medical care, we can live forever. This illusion is important and motivates us to allocate resources—for kidney dialysis and heart transplants, for example—to diminish negatives. But these resources are limited. We are playing a zero sum game." Starr said that the expenditure of society's resources on costly medical technologies to keep elderly people alive may deprive younger, poverty-stricken, sick people of the money they need to restore their health so they can work.

"Illusions have serious real consequences," Starr said. "If the public believes something strongly enough, the government will end up allocating resources. For example, if the news media convince the public that a comet will come soon and wipe us out, we'll spend an enormous amount of money on the space program to try to blow up the comet. Thus, the image that communicators give to the public is very important. Political decisions are based on beliefs, images, illusions, and perceptions."

Science and Risk

The image that communicators give to the public about health risks is based on estimates of health effects provided by scientists. The science of estimating health effects is part of the new field of risk analysis, or risk assessment. In his talk at the workshop, Bob Cumming, founding editor of *Risk Analysis* and a researcher in ORNL's Biology Division, defined


Starr is father of risk analysis.

risk as "the likelihood that something bad is going to happen." Risk involves a probability and a consequence. Even though some risks are only speculative, they can have dramatic impacts on public policy-making.

Consider the risks of nuclear power stations. Said Starr: "So far no public damage has occurred from the operation of nuclear reactors, yet society has invested a large amount of resources in preventive steps to reduce the risk of a nuclear accident." Participants in the workshop suggested that the public thinks that reactors are dangerous because so much has been said about possible risks, because of the nuclear plant accident at Three Mile Island (TMI), and because of the presumed connection between nuclear power and the atomic bomb.

Although the public should not expect scientists to prove that a product or technology is absolutely safe, the public has a right to expect scientists to communicate accurate information. So said Alvin Weinberg, former ORNL director and now director of the Institute for Energy Analysis (IEA) at Oak Ridge Associated Universities.

"Scientists have the responsibility to state clearly what they know and what they don't know," said Weinberg. "I coined the word *trans-science* a few years ago to describe questions that sound like scientific questions but cannot be answered by science. What is the probability that one atom of arsenic is going to cause cancer? is an example of such a question.

"Scientists," he continued, "have been at fault in making incorrect statements that get cast in concrete and therefore affect policy-making. The ozone question is an example. Five years ago, some scientists suggested that chlorofluorocarbons would reduce the earth's protective ozone layer by 15 to 18%, thus allowing more ultraviolet radiation to reach the earth and increasing the likelihood of people getting skin cancer. A National Academy of Sciences (NAS) report in 1982 on the threat of fluorocarbons to the ozone layer stated that the reduction would be 5 to 9%. The consequence of the report was that the federal government proscribed the use of chlorofluorocarbons for spray cans." In the middle of February 1984, a new NAS report stated that fluorocarbons could reduce the amount of ozone in the atmosphere by only 2 to 4%, not as much as 9%, and that there is still uncertainty. "Scientists have to be more careful in stating the limits of their knowledge," said Weinberg. "They should have said it could be a 9% reduction or it could be much lower than that."

Weinberg argued that scientists still have limited knowledge about cancer risks, as shown in a study conducted by the National Toxicology Program. About 7000 animals (of a strain that has a high spontaneous incidence of leukemia) were divided into treatment groups and matched control groups. The treatment groups were exposed to 25 different agents, such as red dye No. 9 and yellow dye No. 3. From one-fourth of these agents, there was an increased incidence of liver tumors in the exposed groups of rats but a *decreased* incidence of leukemia in the same groups. Furthermore, the exposed rats actually lived longer than the unexposed rats. Weinberg and John Storer of ORNL's Biology Division have suggested that this experiment proves the existence of "ambiguous carcinogens"—agents that increase the incidence of some kinds of cancer but reduce the incidence of other kinds.

Weinberg agreed with Starr that "science cannot prove safety" but made the point that scientists and engineers can come up with

Sitting at right of Alvin Weinberg, IEA director, are Bob Cumming, ORNL biologist who spoke at the workshop, and Ernie Silver, editor of **Nuclear Safety.**

technical fixes to make technology safer. "The upshot of the current moratorium on building nuclear reactors," he said, "is that people are going back to the drawing board to come up with inherently safer reactors, including breeders."

The News Media

Most people's perceptions about the health risks of technologies are believed to be based on the information they obtain from the news media. This information may be distorted because of incorrect statements made by scientists or because of the way that reporters present the material.

Carl Goldstein, director of public relations for the U.S. Committee for Energy Awareness, Washington, D.C., spoke to the workshop participants on his perceptions of the news media and how they handle or mishandle news about nuclear energy. He said:

"I don't think the press works out of any deep-seated bias against anything, including nuclear power. I think the press has only one bias, and that's toward the melodramatic. Certainly we can't deny that the development of nuclear energy has provided the press with plenty of melodrama.

"A lot of my reporter friends say that their antinuclear reporting is a sign of their sense of betrayal. They say that we claimed that nuclear power was an immaculate technology that was safe and that we told them incidents like TMI could not happen. But TMI did happen. So they say they cannot afford to turn their jaundiced eye off us for one minute. It's really an unreasonable selective exercise of skepticism. All technologies and especially all energy technologies pose risks to health and safety. Yet the press has been much harsher in its scrutiny of nuclear power than of infinitely more hazardous, often less productive, enterprises."

Starr said that the news media operate as profit-making businesses that seek to win readers, listeners, and viewers by attention-grabbing stories that "claim a new scientific miracle or imminent doom." Journalists, he said, often tell "truth selected to meet the requirements of providing interest and excitement." Because "crying wolf" is more melodramatic than explaining risk uncertainty, Starr said the media often report uncertain risk as probably real.

Scientists can't change the media, said Starr. "The saving grace for the media is that they have a sense of professional responsibility and don't want to hurt the country or force a misallocation of the public's resources. Scientists should therefore do their best to educate the media. For scientists to talk directly to the public is a waste of time; 30 years of their trying to educate the public with programs on radiation has proved futile."

It is Starr's contention that much public discussion by scientists to "explain" effects, such as those of radiation, serve mainly to convince the public that the issue must be important. Social science surveys have indicated that the public is generally not reassured by such discussions.

Dick Smyser, editor of *The Oak Ridger* and president of the American Society of Newspaper Editors, told workshop participants that he disagreed with Starr's point that scientists should abandon their efforts to educate the public. He believes, however, that journalists should receive more education on statistics and probabilities so that they can present them to the public in a meaningful way.

Smyser is well aware that the news media can distort the truth by focusing on single issues, such as the 1983 revelation of the large

"A part per billion is one crouton in a salad that weighs 500 tons."

Betty Anderson, EPA.

losses of mercury over a period of years from the Y-12 Plant. "I think that Oak Ridge is a very good place to live," he said, "that it is not Times Beach East or Love Canal South, as more recent press reports have suggested."

In response to this comment, Starr said that Times Beach and Love Canal may not be dangerous places either, even though the news media have fostered this impression.

Putting Risk in Perspective

How can the news media make risks and probabilities meaningful? Do people understand risks enough for their actions to be affected? Many people have quit smoking presumably because they are aware of the risk that smoking poses to their hearts and lungs. But, as Smyser points out, many people prefer to ride in cars rather than in commercial airplanes, even though planes are shown to be statistically safer. "People do not buckle their seatbelts," he added, "even though statistics show that seatbelts greatly reduce one's chance of being hurt in an automobile accident." The press, he said, is obsessed with the risks of nuclear power, yet people are more likely to become ill or die from breathing sulfur dioxide from coal power plants.

Making these statistical risks understandable to the public is a challenge not only for the news media but also for scientists communicating with reporters. Said Goldstein: "Scientists have failed to portray benefits and risks in terms that the lay public can understand or even to relate these arcane statistics to something that the public can identify with or understand. Most of us haven't a real concept of what these statistics mean. Gordon Riddle, professor of Dartmouth University, wrote a letter to the *New York Times* that defined 'part per billion' in terms that we can understand. 'A ppb,' he wrote, 'is one inch in 16,000 miles, one second in 33 years, one minute in the time that has elapsed since year one, a penny in $10 million, and, for the diet conscious, one crouton in a salad that weighs 500 tons.'"

Goldstein recalled recent news articles that discussed Sandia National Laboratory conclusions that the probability of a reactor accident is 1 in 2 billion per reactor per year. "How do you make that meaningful to a reader? That is the same probability of a star going supernova and wiping out the earth. Had we said that, it might have made a better impression on the news media and the public."

In a recent event at the Connecticut Yankee nuclear power plant, Goldstein said, a relief valve on a waste-gas holding tank lifted for 5 s and allowed 0.33 Ci of radioactive gases to escape through the stack. The added dose rate at the plant boundary was calculated at 1.5×10^{-4} millirem/h. Calculations based on information in Bernard Cohen's new book *Before It's Too Late* show that the health risk from such a dose is equivalent to the risk of driving a car approximately 1 m (3 ft).

Putting risk in perspective means making comparisons between the less familiar and the more familiar (for example, Cohen suggested that the basic unit of risk should be the cigarette). However, there is no guarantee that making comparisons will have the intended effect. Said Weinberg: "As far as the public is concerned, the only thing comparable to nuclear reactors in terms of catastrophic risks is big dams, of which there are 10,000 in the world. The risk of a dam failing is greater than the risk of a reactor meltdown. The problem with these comparisons (made by the California media) is that they didn't make people more comfortable with nuclear reactors; instead, the comparisons made people less comfortable with dams."

Even direct communication about risks to the public can backfire. Betty Anderson, president-elect of the Society for Risk Analysis and director of the Environmental Protection Agency's (EPA's) Office of Health and Environmental Assessment, told workshop participants about EPA efforts to inform the public about the risks of getting cancer.

"Some industrial workers," she said, "have been concerned that they could get cancer from exposure to arsenic. EPA risk assessors estimate that there is only 1 chance in 1000 that workers exposed to

Panelists listen to question from audience.

arsenic will contract cancer. To make risks understandable, we held a workshop for some workers worried about exposure to arsenic. We told them that for every ten Americans who smoke during their normal lifespan, one will get lung cancer and that one in five Americans will die of cancer, regardless of whether or not they are exposed to arsenic. We found that the people who had received information in workshops about cancer risks still had the same perceptions of the dangers of cancer mortality as the people who had not attended the workshops."

Weinberg noted that many people also worry about dying of botulism, even though hardly anyone dies of botulism poisoning nowadays. People seem to have culturally ingrained fears that are not justified by real events. People also seem to have a need to blame technology for their ills. Thus many people consider nuclear power much more dangerous than the natural radon in the air they breathe in their homes. In his paper "Witches, Floods, and Wonder Drugs," Bill Clark of IEA makes the analogy between our current sources of anxiety and the fear of witches that swept Europe in the 14th and 15th centuries. Europeans then killed half a million people believed to use witchcraft to afflict children and cattle. Some technologies may be perceived as today's witches.

Perception and communication of risk are shaped by culture, said Cumming. "The news media are a part of our communication culture. They are not consciously steering society wrong, and I don't think they are guilty of murder when they shape perceptions so that coal power (which kills more people) is substituted for nuclear power, as Bernie Cohen suggests. I suggest that the whole process of dealing with health risks is a cultural process. There are philosophical and quality-of-life considerations. The public is not a passive receptor of information; the culture is much more dynamic. People accept or reject information on risks largely based on cultural considerations."

Risks of a Free Society

Weinberg wondered if technology can continue to prosper in the open society of the United States. "It's a point we cannot ignore. The places where nuclear energy is doing the best are societies that are less free, including the Communist world, Taiwan, and Korea. I don't know what the answer to that is. If the choice is between nuclear technology and the open society (with a free press), I would choose the open society even if that meant we had to give up nuclear technology."

Weinberg, Goldstein, and Starr are concerned that the news media are too willing to air the antitechnology views of a minority of articulate scientists. Asked Weinberg: "How do we deal with the capture of the open society by the coercive utopians? Will the free press be sufficiently free, open, and strong to resist them?"

"I think the press as a whole has been far less skeptical about a handful of extremely articulate dissidents than it has been of the scientific establishment," said Goldstein. "As applied to radiation risk, for example, talk by dissidents has created a public impression that after all these years, there is still a raging controversy over radiation effects."

The public is unduly concerned about low-level environmental effects, workshop participants agreed. Anderson noted that most studies agree that lung cancers are caused largely by smoking, with air pollution being a secondary cause.

"In my opinion," said Weinberg, "life could get worse not because of low-level environmental effects but because of the real problem of a nuclear weapons confrontation. I'm delighted that the coercive utopians who killed nuclear energy are now moving on to nuclear weapons. Nuclear arms is by so many orders of magnitude the real issue, unlike the low-level environmental effects on which we have spent so much money to measure or prevent."

For the news media, the challenge is to put the health risks from environmental agents in a perspective that is less likely to arouse groundless fears and cause a misallocation of the nation's resources. ornl

Tom Oakes is head of the Department of Environmental Management in ORNL's Environmental and Occupational Safety Division. He holds an M.S. degree from Virginia Polytechnic Institute and State University and has completed work on a Ph.D. degree in environmental engineering from the University of Tennessee. Oakes has been at ORNL since 1975. Tom Kitchings is surveillance task leader in the Department of Environmental Management. A native of Oak Ridge, he has been an ORNL staff member since 1966. Before joining the Environmental and Occupational Safety Division in late 1983, Kitchings was a member of the Environmental Sciences Division and served as coordinator of the Oak Ridge National Environmental Research Park. He holds an M.S. degree in biology from New Mexico Highlands University. His main research interest is the environmental transport of contaminants. Helen Braunstein is task leader for environmental risk assessment in the Department of Environmental Management. She has been at ORNL since 1973, working in the Reactor Chemistry, Information, and Energy divisions before joining the Environmental and Occupational Safety Division in 1981. She holds a Ph.D. degree in physical chemistry from the University of Maine and an M.P.H. degree in environmental and occupational health and safety from the University of Tennessee. She is a coauthor of two books, *Biomass Energy Systems and the Environment* and *Environmental, Health, and Control Aspects of Coal Conversion.* Here, Oakes (center), Kitchings, and Braunstein examine the newly installed automatic sampling and monitoring system at White Oak Creek.

ORNL and the Environment:

Views of State and Federal Regulations

By THOMAS W. OAKES, J. THOMAS KITCHINGS, AND HELEN M. BRAUNSTEIN

On August 23, 1983, a compliance evaluation inspection of Oak Ridge National Laboratory was conducted by the Tennessee Department of Health and Environment and the U.S. Environmental Protection Agency (EPA). The inspection was conducted because the existing National Pollutant Discharge Elimination System (NPDES) permit had expired. Since a valid permit is necessary for the Laboratory to operate, personnel from the state and EPA came to review ORNL monitoring and treatment systems and to audit discharges to local streams. This was the first time that the Laboratory had been subjected to such an inspection and the first time that its compliance with state laws—that is, the Tennessee Water Quality Act and Hazardous Waste Management Act—had been examined by state officials.

What had changed from past practice was the role of the state in regulating federal facilities within its borders. Prior to 1983, EPA administered environmental regulatory authority at ORNL; and although the state could have

John Murphy, left, examines the Melton Branch water-monitoring weir during normal flow. The flow through the V-shaped weir is so low that Murphy can stand on the dam. At right, Jay Story stands above the dam to observe the weir at high flow. During high flow an ultrasonic sensor, which monitors the water level in the weir, activates a second sampling system to collect flow-proportional samples representative of the high-flow conditions. One reason that water samples are taken at both high and normal flow is to determine if any radioactive materials are being leached from the ORNL burial grounds during rainstorms. The samples are routinely analyzed for nonradiological parameters to meet state and federal requirements. On May 7, 1984, when water flowed over ORNL dams at a very high rate, the flow was measured at 4900 L/s (1300 gal/s), a factor of 16 higher than normal flow, which is about 300 L/s (80 gal/s).

assumed that responsibility from EPA, it had not taken action until last year (see box on p. 50).

The state's action was consistent with Executive order 12088, which requires federal facilities to comply with all applicable state and local environmental regulations. The Executive order not only requires compliance but also acknowledges the application of sanctions (e.g., fines, penalties, and orders to cease operations) by state and local governments for enforcement of standards. The compliance evaluation inspection will undoubtedly influence ORNL's programmatic and environmental future. But, in focusing additional attention on ORNL and the environment, it also initiated some dialogues that are still continuing and that ultimately will result in a higher quality environment for both ORNL and the surrounding area. The Tennessee Water Quality Control Act and the Federal Water Pollution Control Act (FWPCA), as amended by the Clean Water Act, share a common dictate—to preserve and protect the quality of communally-shared waters. The NPDES permit is the key instrument for fulfilling that goal.

In 1983 the State of Tennessee sought for the first time to acquire the right to regulate ORNL's discharges to the environment. Recently the state conducted a compliance evaluation inspection and recommended that ORNL take action to solve its environmental problems. In this second part of a series, the authors discuss steps that ORNL is taking to respond to the inspection report and the legal issues pertaining to environmental management at the Laboratory.

When ORNL's original permit expired in 1979, an application for renewal was filed with EPA; and because tighter standards had been set by EPA in the five-year period since the permit's issuance, negotiations were started between the U.S. Department of Energy and EPA to establish some new standards and additional monitoring points. While these negotiations were in progress, the compliance evaluation inspection was requested by the state. Following the inspection, a notice of noncompliance was sent to DOE, which stated in part: "The inspection, along with a review of documents, revealed serious environmental problems related to ORNL. Although the present permits are inadequate, there have been numerous violations, and studies have documented chemical and radiological contamination of area streams, rivers, and groundwater. Much of the pollution is apparently the result of past

Enforcing Environmental Regulations: Federal–State Interactions

Most federal environmental statutes contain provisions for delegating to the states the responsibility for implementing and enforcing federal standards. Under the Clean Water Act, for example, EPA is the issuing authority for all NPDES permits in every state until individual states elect to administer the permit program. When the State of Tennessee was ready to take over the program, it had to obtain EPA approval of the program by (1) submitting a state plan that provides for pollution control that is equal to or more stringent than that specified in the act and (2) assuring EPA that the state has adequate personnel, funding, and authority (laws) to carry out the plan.

When a state becomes the issuing authority, permitting procedures are generally expected to be comparable to EPA procedures, but notable exceptions can occur. State laws can vary considerably in definitions, interpretations, and opportunities for judicial appeal. "Waters of the state" can be defined much more inclusively than "waters of the United States," especially regarding public and private access. A "point source" of discharge may be interpreted by the state to mean any source including a surface waste impoundment, from which discharges are not normally anticipated, except under unusual conditions such as excessive rainfall. On the other hand, for EPA, under the same circumstances, the "point source" of discharge may be specified as the "discrete conveyance" (such as a pipe or ditch) through which all discharges leave the facility site. Unlike EPA, a state is not required to provide for an adjudicatory hearing for appealing the state's actions or questioning the applicability of its effluent standards, prohibitions, or treatment requirements. The State of Tennessee, however, does provide for a hearing before the Water Quality Control Board.

Another interesting component of state-federal interaction in environmental regulatory enforcement relates to federal facilities. Executive order 11752, "Prevention, Abatement, and Control of Pollution at Federal Facilities," issued on December 17, 1973, made it clear that federal facilities were to be included under EPA environmental review. This order called for compliance with all federal environmental laws. However, it also stipulated: ". . . this order is not intended, nor should it be interpreted, to require Federal facilities to comply with State or local administrative procedures with respect to pollution abatement and control." Federal facilities were instructed

Linda Spurling collects data at a sampling station at White Oak Dam.

to cooperate with state and local governments in meeting their standards—but only substantively, not procedurally. In other words, state and local governments could not inspect, issue permits to, or penalize federal facilities.

In compliance with Executive order 11752, ORNL applied to EPA for an NPDES permit, which was issued in 1974. The permit was for three NPDES monitoring points. It specified nonradiological effluent limitations and called for monitoring of the discharges "to receiving waters named White Oak Creek, a tributary of the Clinch River, and Melton Branch, a tributary of White Oak Creek." ORNL's permit conformed to EPA policy, which at that time considered the facility boundary as the point of discharge. The permit did not require ORNL to monitor its discharges from specific processes; rather it called for monitoring of the outfalls into waterways that flow through the Oak Ridge Reservation. That the Laboratory's activities were not viewed as typical is reflected in this statement in the permit: "Nothing in this permit shall be deemed to supersede the requirements of the Atomic Energy Act of 1954, as amended, for the protection of restricted information."

On October 13, 1978, Executive order 11752 was revoked. In its place was issued Executive order 12088, which is virtually the same as 11752 except that this order, which is still in force, specifically requires federal facilities to comply with the applicable state and local environmental regulations.

activities at ORNL. As a result, there are violations of the Tennessee Water Quality Control Act. . ." The problems referred to involve primarily permitting, compliance, and on-site water quality concerns. As stated in the 1983 DOE environmental monitoring report, there is no imminent danger to public health. Nonetheless, the significance to ORNL of the state's conclusions should not be underestimated.

Old and New Problems

Many of ORNL's problems are old problems. They derive from the early days before most of the knowledge about environmental effects was available. In fact, the oldest problems are the worst ones because the magnitude of a given environmental problem is often directly proportional to its age, and the difficulty associated with finding a solution is equally age related. Nonetheless, Martin Marietta Energy Systems, Inc., is as concerned with remedying old problems as it is committed to preventing new ones.

Historically, ORNL's disposal of gaseous, liquid, and solid materials was always undertaken to minimize the hazard both to the environment outside ORNL's controlled zone and to the employees within that zone. During the past 40 years, however, government regulations and environmental standards regarding discharges have changed considerably. As a result, disposal technology considered adequate 10 to 15 years ago is no longer acceptable under today's more stringent regulations. Currently, federal and state regulations require ORNL's environmental management staff, waste management operations staff, and Martin Marietta Energy Systems' Environment, Health, and Safety personnel to address two types of challenges: (1) controlling releases from our current operations and (2) engineering remedies for problems resulting from 40 years of past operations.

The ORNL Department of Environmental Management staff is responsible for evaluating ORNL's compliance with all local, state, and federal regulations and guidelines that relate to the discharge of radioactive and nonradioactive materials into the environment. One of the department's functions is to determine concentrations of radionuclides and selected chemical constituents and physical parameters in various samples collected at numerous sites in and around the ORNL environs.

The new Melton Branch weir (left) is a modern sampling station, an improvement over the old weir sampling station which was like the one seen here at White Oak Creek (right). The old weir pictured here has been replaced by a new one. Melton Branch and White Oak Creek are two NPDES sampling points.

Among these sites are the three NPDES monitoring points located on White Oak Creek, Melton Branch, and the ORNL Sewage Treatment Plant. White Oak Creek and Melton Branch are equipped with automatic monitoring and sampling systems. Samples are collected; and data are recorded on water flow, pH (acidity level), dissolved oxygen, temperature, and conductivity. In addition, during storms, when the water flow exceeds the normal measuring system capacity, an alternative high-flow sampling system is automatically activated to collect flow-proportional samples representative of the high-flow conditions. The system is designed

This is the second in a series of articles on ORNL's impact on the environment. The third article, to appear in the next issue, will deal with resource management and will cover such topics as the preservation of endangered green plants, the management of the deer population, and the use of sewage sludge on the Oak Ridge reservation.

The sewage treatment pond lagoons (center left) and coal-pile runoff basin (lower left) were cited by the State of Tennessee as sources of environmental problems. At right is the sewage treatment plant.

to monitor for possible leaching or runoff from contaminated areas that usually have no discharge. Daily samples taken at the sewage plant are analyzed in the field for pH and chlorine concentration, and, as called for in the permit, samples are tested on a weekly or monthly interval for other parameters, such as biological oxygen demand and fecal coliform.

State Inspection

Problems identified as a result of the compliance evaluation inspection were discussed in an October 26, 1983, communique from the Tennessee Department of Health and Environment to the Environmental Protection Branch of the Oak Ridge Operations Office of DOE. The problem areas and specific concerns identified by the state include the following.

●*Sewage treatment plant.* Built in 1973, this plant is no longer providing adequate treatment. Periodic discharge violations have occurred.

●*Low-level radioactive waste treatment system.* This system is beset with leaky pipes that allow radionuclides to be released into the sewage treatment plant and to the environment.

●*Laboratory waste ponds.* These retention ponds, which hold liquid radioactive wastes, could be a potential source of radioactive material to nearby groundwater.

●*Coal-pile runoff basin.* Historically, this basin has been cited as the culprit for frequent pH violations that have occurred in White Oak Creek.

●*Groundwater.* The inspection team expressed concern that DOE environmental monitoring reports lacked the data needed to predict the extent to which radionuclides could be leached by groundwater and transported off site.

●*Burial grounds.* The seepage of radioactive materials from the old burial sites into both surface water and groundwater has historically been a problem, and it has received much study and planning.

●*On-site streams.* The inspection team noted evidence of sediment contamination and a decline in water quality and the health of aquatic life, particularly in White Oak Creek. Discharges from ORNL facilities into these streams were blamed for the adverse effects.

●*White Oak Lake.* The inspection team expressed numerous concerns about the possibility of transport of radionuclides buried in the lake's sediments by sediment movement into the Clinch River. According to the inspection team's report, the lake "presents an ongoing and primary source of radioactive contamination of fish, water, and sediments in the Clinch and Tennessee rivers."

Technical Fixes Planned

The environmental problems identified by the inspection team were, for the most part, ones that the ORNL environmental management and nuclear waste management staff had been aware of for several years. Members of the environmental management and engineering staff and other ORNL staff members had, in fact, developed a five-year environmental plan directed toward solving these problems with technical fixes. Some

These two ponds used as settling basins for low-level radioactive wastes are scheduled for decontamination and decommissioning in the late 1980s. By taking these ponds out of service, ORNL will resolve an environmental issue raised by the Tennessee Department of Health and Environment.

This burial trench for radioactive wastes has been capped with asphalt to reduce the surface flow of water into the trench. This "fix" lowers the risk that surface water will be able to enter the burial site to leach radioactive materials and transport them elsewhere.

Runoff from the coal pile at the ORNL steam plant is treated in this basin to remove solids and reduce the acidity level. After treatment, this water is discharged into White Oak Creek.

of these planned projects have received funding for the next fiscal year and others are scheduled for funding in fiscal years 1986–1989. DOE and Martin Marietta Energy Systems are aggressively seeking congressional authority with the highest priority for discretionary funding to implement these projects.

A series of engineering projects to upgrade the sewage treatment facility are scheduled and funded and, when completed, should provide the treatment necessary for compliance with the state's discharge guidelines. The leaking pipes in the low-level radioactive waste treatment system are being systematically inspected and replaced. Because this system has about 5 km (3.2 mi) of piping, a task force is determining the priority piping sections that should be replaced first. To date, approximately 100 m (375 ft) of pipe has been excavated and replaced. Piping will continue to be replaced until the system is completely free of leaks.

The Laboratory waste ponds, another environmental problem identified by the state inspection team, are scheduled for decontamination and decommissioning in a joint effort by the environmental management and waste management staffs. These ponds should be removed from service before 1990.

ORNL has taken steps to address the problem of coal-pile runoff, which occurs when rainwater falls on the pile of coal used to fuel the steam plant and produces an acidic leachate high in dissolved iron and aluminum. Before being discharged into White Oak Creek, coal-pile runoff is collected in an impoundment, where the runoff water is treated to adjust the pH and to remove solids from the neutralized water. Funds have been provided for adding a clarifier to remove the solids as a sludge that can be dewatered and disposed of as a nonhazardous waste.

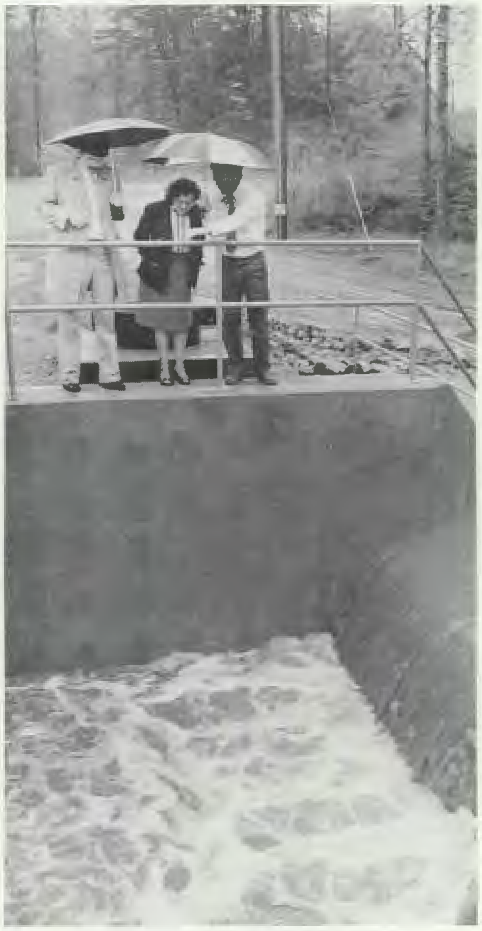
The movement of radionuclides in groundwater occurs primarily from seepage in burial grounds. This movement has been monitored by the environmental management staff quarterly by collecting samples from 50 wells located throughout the burial ground sites. In addition to radionuclides, the groundwater is also analyzed for trace organic compounds and metals. Problems associated with possible groundwater pollution are receiving high-priority attention at the Laboratory.

The migration of radionuclides from the solid and liquid waste disposal areas has been the focal point of considerable research in the past. This research effort is leading to recommendations of technological solutions that can be implemented by our engineers. For example, studies of radionuclide transport from the six solid waste disposal areas have shown that area No. 4 is the largest contributor of strontium-90 to surface water and groundwater at ORNL. In examining how strontium-90 migrated from area No. 4 to both surface water and groundwater, ORNL researchers concluded that the migration was caused by water flowing over the surface. The researchers suggested that a large portion of the migration of strontium-90 from the No. 4 waste site could be eliminated by diverting the water coming down the slope above the waste site. Subsequently, ORNL scientists and engineers devised an effective solution to the problem by designing and installing a storm-water channel within the waste site and a storm-water diversion system above the site. The latter system intercepts rainwater before it reaches area No. 4 and routes it to a natural drainage path that is uncontaminated.

Continued efforts by the various research and development and support and service staffs at the Laboratory to find solutions to the problems affecting White Oak Creek and Melton Branch should allow the reestablishment of viable biological communities in these streams. White Oak Lake, however, remains a problem for which the Laboratory does not yet have a solution. Various options are currently being reviewed for cost estimates and environmental impacts. These are (1) rerouting White Oak Creek and Melton Branch so that they no longer pass through White Oak Lake, (2) stabilizing the sediments to prevent their movement out of the lake bed, (3) constructing a channel through the lake bed so that water from the creeks does not contact the sediment, (4) removing the contaminated sediment from the lake, and (5) allowing the lake to remain unaltered, enabling clean sediments to continue to collect in the lake, thus covering the contaminated sediments and isolating them from the environment.

Jurisdictional Issues

The state inspection team identified two issues of special importance to ORNL. The first issue is whether all streams on the Oak Ridge reservation—including those sections within the ORNL facility boundary—would be classified as state waters, which would then make them subject to the Tennessee Water Quality Control Act. Classification of on-site streams as the property of the state would mean that the effluent discharge permit that had been issued to establish instream monitoring points would no longer be valid. Furthermore, ORNL's historic use of certain streams, particularly those in the Melton Branch–White Oak Creek



On a rainy day in May, Oakes, Braunstein, and Kitchings observe high flow at the Melton Branch weir.

watersheds as discharge collection waterways, would have to be modified because permits could be issued for all points of discharge within the facility boundary rather than for the streams themselves. This change could result in an increase in the number of NPDES points from 3 to as many as 25, each of which could need a monitoring station.

The second issue concerns whether radiological parameters will be included in the NPDES permits at ORNL and whether state and EPA regulations will be applied to ORNL's radioactive discharges. ORNL, along with many other DOE facilities, has special obligations and requirements assigned to it under the Atomic Energy Act of 1954 and its amendments. The state inspection report has questioned the right of this act to exempt ORNL from complying with regulations on discharges of radioactivity to waters in the state, as specified in the Tennessee Water Quality Control Act. However, there is a legal precedent that relates to this issue of exemption.

In 1976 the Supreme Court of the United States held in *Train* vs *Colorado Public Interest Research Group* that source, by-product, and special nuclear materials (as defined by the Atomic Energy Act) are not included under the FWPCA definition of *pollutants* and that the regulation of source, by-product, and special nuclear materials is exclusively reserved for the Atomic Energy Commission—now DOE and the U.S. Nuclear Regulatory Commission. Because the state's water quality regulatory authority derives from EPA, it also falls under the Supreme Court decision, which essentially says that federal-state authority does not extend to source, by-product, and special nuclear materials but only to radium and accelerator-produced isotopes. However, the Supreme Court also noted that under the Atomic Energy Act the absence of a state role in setting radioactive discharge limits was in marked contrast to the FWPCA scheme; nonetheless, the court concluded that Congress intended that the regulating scheme of the Atomic Energy Act be unaltered. In view of this decision, the DOE position is that it is inappropriate to include in NPDES permits at ORNL any radioactive discharge limits for source, by-product, or special nuclear materials. This jurisdictional issue is not yet resolved.

A very recent U.S. federal district court decision handed down in Knoxville (April 13, 1984) may have an impact on environmental management activities at ORNL. The decision states that DOE must comply with federal environmental laws regarding the handling, storage, and disposal of hazardous materials under the Resource Conservation and Recovery Act (RCRA). In fall 1983 two environmental groups, the Legal Environmental Advisory Foundation and the Natural Resources Defense Council, filed suit asking that DOE comply with federal waste disposal and water quality laws at the Y-12 Plant. In January 1984 these two groups were joined in the suit by the Tennessee Department of Health and Environment, which sought a declaration from the court that DOE is subject to the federal hazardous waste disposal laws and therefore to the Tennessee hazardous waste law. The state was not seeking a ruling concerning water quality laws.

DOE responded to the suit by claiming exemption from federal environmental laws under the 1954 Atomic Energy Act. In February 1984 DOE and EPA signed a memorandum of understanding that would leave hazardous-waste regulations and control at DOE facilities in the hands of the two agencies. The agreement established a hazardous-waste and radioactive-mixed-waste program for DOE that is comparable to waste management approaches called for by RCRA provisions. Generation, transportation, treatment, storage, and disposal of these wastes were covered in the agreement, which gave EPA the right to inspect the DOE plants for violations but restricted state officials to consultations with EPA.

Despite the agreement between DOE and EPA, in April 1984 the federal district court ruled that the Y-12 Plant must comply with the permitting requirements of the federal environmental protection laws at issue, namely, RCRA and FWPCA, as amended by the Clean Water Act. Even though the suit was directed specifically at the Y-12 Plant, 47 other DOE facilities may be affected. Noncompliance with the law may draw penalties and fines. This decision is not expected to impact ORNL in the area of hazardous waste because the Laboratory has been in complete compliance with RCRA since 1981.

Outlook

ORNL has continually and systematically addressed its environmental problems. In doing so, it usually selected problems in the order of severity, from the most to the least severe, so that the worst problems would be tackled first. As a research institution, virtually all problems under study, including in-house environmental issues, become part of the reporting process. Thus, because of the research orientation, reports of ORNL investigations sometimes portray problems at the Laboratory in greater detail than is necessary for regulatory compliance.

In addition, in assessing environmental situations in which data are insufficient, a worst-case situation has often been assumed as part of the analysis. This approach provides a dual benefit: (1) if new data are not forthcoming, the analysis remains conservative, and recommended actions provide an extra margin of safety, and (2) if new data become available, the revised analysis may indicate less impact than predicted by the assumed worst case, thus calling for less stringent control measures than had been anticipated. In their compliance evaluation inspection report, the state inspection team used ORNL reports extensively in their evaluation. Nonetheless, they acknowledged our efforts and suggested improvements to hasten our compliance with state standards. According to the report:

"In general, ORNL has done an excellent job, studying, monitoring, and documenting environmental problems related to the X-10 site. Improvements have been made over the years; however, numerous problems exist. The first step toward total compliance is the issuance of realistic permits that will adequately monitor discharges at their source and, through violations, will point out problems. Positive actions must be taken to improve operations so as to bring discharges into compliance with new permit parameters. Plans and implementation schedules for cleanup and decontamination must be established to remove on-going sources."

ORNL staff members have been working toward full compliance with state and EPA environmental discharge criteria and will continue to do so according to our five-year environmental plan. We will be using the expertise of ORNL staff members and outside people to help us resolve our problems. ORNL staff members are also being encouraged to help the Laboratory meet these new criteria. "It is important that each employee take individual responsibility for eliminating or reducing any discharges associated with Laboratory work," says ORNL Director Herman Postma.

By working with state and federal regulatory representatives, we believe that an understanding of our problems can be reached and remedial measures taken that will ensure a high-quality environment at the ORNL facilities and in surrounding areas

awards and appointments

Herman Postma has been appointed to the Tennessee Higher Education Commission by Governor Lamar Alexander.

Alexander Hollaender, former director of ORNL's Biology Division, has received the Enrico Fermi Award.

Bill G. Eads has been named director of the Instrumentation and Controls Division.

C. W. (Woody) White and **Bill R. Appleton** have been elected president and vice-president, respectively, of the international Materials Research Society.

John Trabalka has been named manager of the Global Carbon Cycle Program of ORNL's Environmental Sciences Division.

ORNL's Pressurized-Thermal-Shock Test Facility has been given the Outstanding Engineering Achievement Award of the year by the Oak Ridge Chapter of the Tennessee Society of Professional Engineers. Award recipients were **Grady Whitman**, **Norman Durfee**, and **Robert Delagrange**.

Robert B. Cumming has received the Outstanding Service to Area of Risk Analysis Award from the Society for Risk Analysis.

Susan K. Whatley has received the Distinguished New Engineer Award from the Society of Women Engineers.

The ORNL *Review* has received an award of excellence in the house organ category in the 1983–84 International Technical Publication Competition sponsored by the Society for Technical Communication. **Carolyn Krause**, editor, **Jon Jefferson**, associate editor, and **Bill Clark**, design director, were the recipients of the award. **Carolyn Krause** also received an award of achievement in the news article category for "Clean Water from Synfuels Plants," ORNL *Review*, Summer 1983.

Dick Engel has been named technical assistant to Murray Rosenthal, Associate Director for Advanced Energy Systems.

Jane L. Patterson has been appointed ORNL's affirmative action coordinator.

Samuel S. Hurt has been named reactor experiment coordinator, and **Thomas L. Dahl** has been appointed administrative supervisor for operations at three of ORNL's six research reactors—the High Flux Isotope Reactor, the Tower Shielding Facility, and the Health Physics Research Reactor.

In the "Battle of the Graphic Artists," a computer graphics competition sponsored by the ISSCO software company, **Morris Slabbekorn** and **Bruce Johnston** received gold medals and tied for the grand prize, and **Peggy Marsh** won a silver medal.

At the 1984 publications competition sponsored by the East Tennessee Chapter of the Society for Technical Communication, the Francis E. McKinney "Best of Show" award was given to the ORNL *Review* (**Carolyn Krause**, editor, **Jon Jefferson**, associate editor, and **Bill Clark**, design director). The following ORNL staff members received awards: **John Seddon** and **Carl H. Petrich**, award of excellence in the category of technical reports for *Management of Public Impacts in Surface Mining* and award of merit in the same category for *Case Studies: Developing Land Uses in Surface Mine Reclamation*; **H. H. Haselton** and **W. R. Becraft**, award of merit in technical reports for *The National RF Technology Research and Development Program Plan*; **Jon Jefferson**, **Lydia Corrill**, and **Bob Eldridge**, award of distinction in newsletters for *Lab News*; **Robert L. Jolley** and **Vivian A. Jacobs**, award of merit in books for *Water Chlorination: Environmental Impact and Health Effects*; **Carolyn Krause**, award of excellence in scholarly and professional articles for "Fuel Reprocessing: A Futuristic Look" and "Safeguarding Reprocessing Plants," ORNL *Review* and award of merit in the same category for "Hot Water District Heating for St. Paul," ORNL *Review*; **S. W. Moeller**, **L-S. C. Sun**, and **Sharon McConathy**, award of merit in scholarly and professional articles for "Failures in Air-Cleaning, Air-Monitoring, and Ventilation Systems in Commercial Nuclear Power Plants, 1978–1981," *Nuclear Safety*; **R. G. Wymer**, award of achievement in periodic activity reports for *Chemical Technology Division Progress Report for the Period April 1, 1981, to March 31, 1983*; **Nancy Norton** and **Charles Hagan**, award of excellence in promotional materials for *The ORNL Library System*; **Carolyn Krause** and **Bill Clark** (and former staff member Barbara Lyon), award of merit in promotional materials for *ORNL and World Energy Uses: ORNL* Review, *Summer 1982*; **William B. Cottrell**, **Sharon McConathy**, and **Joan F. Roberts**, award of distinction in whole periodicals for *Nuclear Safety*;

Carolyn Krause, Jon Jefferson, and **Bill Clark,** award of distinction in house organs for the ORNL *Review*; **Ann Travis** (and former staff members J. Paul Blakely and P. S. Baker), award of distinction in style guides for *Nuclear Division Document Preparation Guide*; **Deborah S. Barnes** and **Beverly Y. Wilkes,** award of excellence in style guides for *Writer's Manual for Publishing in Semitechnical Journals*; **Bill Clark, Steven Wyatt,** and **Dick Swaja,** award of achievement in brochures for *Dosimetry Applications Research Facility*; **Carolyn Krause,** award of distinction in trade and news articles for "Silver Recovery from ORNL Wastes," ORNL *Review*, and award of excellence in the same category for "Clean Water from Synfuel Plants," ORNL *Review*; **Jon Jefferson,** award of merit in trade and news articles for "ORNL Helps Launch Design of Reactors for Space," *Lab News*.

Fran Sharples has been appointed to the Recombinant DNA Advisory Committee of the National Institutes of Health. She also has been named an American Association for the Advancement of Science Congressional Science and Engineering Fellow.

John B. Bates and **Edward E. Gross** have been elected Fellows in the American Physical Society.

Yok Chen has been elected a Fellow of the American Ceramic Society.

Joel R. Buchanan has been named head of the Nuclear Operations Analysis Center, replacing William S. Cottrell, who retired in April. Buchanan was also appointed program manager for U.S. Nuclear Regulatory Commission Information and Evaluation Programs at ORNL.

Ernest G. Silver has been appointed editor of the journal *Nuclear Safety*, which observed its 25th anniversary this year. Silver replaces William S. Cottrell, who had been the editor since the journal was founded in 1959.

B. A. Berven has been elected chairman of the Environmental Section of the Health Physics Society Standards Committee.

M. Cristy and **R. W. Leggett** have been named members of the Task Group on Dose Calculations of Committee 2 of the International Commission on Radiological Protection.

Keith F. Eckerman has been named a member of the U.S. Nuclear Regulatory Commission (USNRC) Advisory Group for Revision of USNRC's Radiological Health Effects Model.

Herbert Inhaber has been appointed a member of the Editorial Board of *Risk Abstracts*.

G. D. Kerr has been named ORNL's representative to the Coordination Information Center of the U.S. Department of Energy and chairman of the Committee on State and Federal Regulations of the East Tennessee Chapter of the Health Physics Society.

D. C. Kocher has been named technical advisor to the Science Advisory Board of the U.S. Environmental Protection Agency.

Thomas G. Matthews received an Appreciation Award for Distinguished Service from Washington State University, sponsor of the International Symposium on Particleboard.

C. W. Miller has been named consultant to the Committee on Reactor Safeguards of the U.S. Nuclear Regulatory Commission.

Janet Swift has been appointed assistant to Fred Mynatt, Associate Director for Nuclear and Engineering Technologies.

Susan G. Winslow has been named technical assistant to Anthony P. Malinauskas, director of Nuclear Regulatory Commission programs at ORNL.

Nancy V. Taylor has been certified for membership in the Institute of Certified Records Managers. She is the only ORNL employee so certified.

Donna Griffith has been elected president and **Susan Hughes** has been elected second vice-president of the East Tennessee Chapter of the Society for Technical Communication.

William O. Harms has received a Distinguished Engineering Alumni Award from the College of Engineering of Wayne State University. He is one of eight charter members of the college's Alumni Hall of Fame.

Carl A. Burtis has been elected to a three-year term on the Board of Directors of the American Association for Clinical Chemistry.

W. J. Lackey has been appointed a member of the American Ceramic Society's Programs and Meetings Committee.

J. Stephen Ivey has been named Inspector of the Year by the Tennessee Section of the American Society for Quality Control.

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During a rainy day in May when water flow was unusually high, Helen Braunstein, Tom Oakes, and Tom Kitchings checked the new storm-water diversion system near solid waste storage area No. 4. Before this system was installed, water during high-flow periods used to cross the road and flow across the burial area. Now, the water is funneled along the road to an uncontaminated area. *See article on p. 48.*