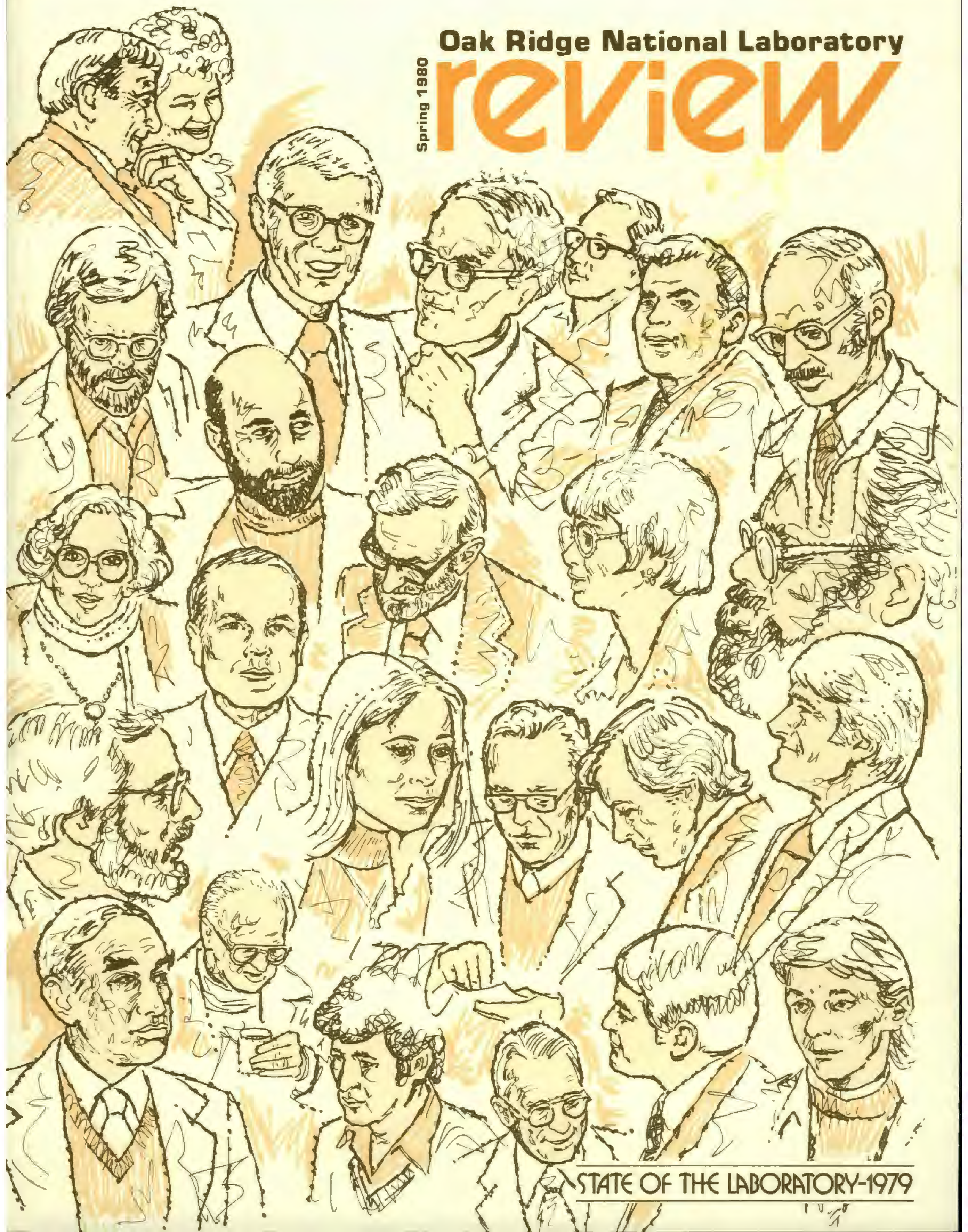
Oak Ridge National Laboratory
review
Spring 1980



STATE OF THE LABORATORY-1979

THE COVER: The past year has seen the culmination of a five-year trend at the Laboratory toward increasing interaction with other agencies and the private sector. Both in the management of subcontracts and in the offering of staff expertise outside and across its own disciplines, ORNL has made growing contributions to the nation's technology. This direct contact and transfer of science formed the theme, ORNL as Consultant, of Herman Postma's State of the Laboratory address, delivered last January.

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Oak Ridge National Laboratory

review

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DEPARTMENTS

OAK RIDGE NATIONAL LABORATORY
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STATE OF THE LABORATORY-1979

ORNL as Consultant

By HERMAN POSTMA

If, at the outset of this new decade, we pause to take stock of events in the headlines both here and abroad, at least one theme becomes evident and will become more evident to all of us with each passing year. This recurring theme is that energy—its availability, cost, and control—is having an increasing impact on national affairs and on the global political order. Where and how we go from here will obviously depend to no small extent on how successfully we as a nation can manage our energy future.

As a mission-oriented laboratory whose primary focus is on energy, ORNL has a unique opportunity to help shape that national destiny. How successful we and the rest of the technical community are in wrestling with the problems of energy supply, demand, and conservation—in 1980 and throughout this decade—will be a crucial factor in our national well-being and world stability. I feel that no task is more urgent or compelling than the one we are facing. The challenge and the opportunity are ours.

This past year was not just another year for ORNL or for anyone. It was a year of events in energy and politics that continue to astound and influence us all. Many of those events set a course in the commitment of this country to research and development areas that will greatly affect the Laboratory for years to come.

In only one respect was 1979 an ordinary year for ORNL. That was in the expected extraordinary scientific achievements, exciting technological results, and quality accomplishments. However, as is usual in this address, I can only give you a small sample of those technical highlights.

Mainly because of events such as Three Mile Island (TMI), 1979 was a most unusual year for ORNL. We were called upon to be consultants, catalysts for decisions, and, in some cases, brush fire artists. Even though 1979 was unusually active, responding in the above capacities is an accustomed role for ORNL and one that serves the Department of Energy (DOE) and the country well. I will expand on this role later, as it forms the theme for this address.

In 1979 there emerged the maturing and culmination of a number of important directions that had been established in the mid-1970s. Although at times somewhat disquieting, these changes have prepared ORNL for new missions, new roles, and new ways of doing things that will be characteristic of DOE's approach to solving national energy problems.

The major technology-oriented programs (fission, fusion, fossil, and conservation) grew rapidly during the 1970s. Fossil energy and conservation grew from embryonic efforts to full-fledged, mature companions to our traditional areas of expertise. We anticipate that the fusion and fossil energy programs, in particular, will continue to increase in the coming decade.

On the other hand, I am concerned that the applied technology programs grew much faster than those for the basic sciences, thus disrupting the balance I believe necessary. In the coming years the balance must be restored through concerted efforts by all of us.

The new missions assigned to the Laboratory beginning in 1975 allowed both strong growth and substantial changes in programmatic directions. Now, with a maturing of those programs, overall personnel levels will show only slow growth. Even within that constraint, however, substantial change will be necessary and possible because of the flexibility and breadth of the Laboratory's research staff.

We have by intent begun to interact increasingly with the Tennessee Valley Authority, industry, and universities to build the broader base that will be necessary to demonstrate and pave the way for commercial application of R&D developments. The goal is to create liaisons, extend our strengths, and provide for better use of Laboratory resources. Such movement has been aided by new technical program management responsibilities assigned by DOE. We are increasingly involved in the technical direction of major R&D programs in areas where we have expertise.

Many of our important technology development and demonstration initiatives now involve industrial partners, as evidenced in the fusion program with the Engineering Test Facility Design Center, the ELMO Bumpy Torus proof-of-principle experiment, and the Large Coil Test Facility; in the fossil program with the atmospheric fluidized-bed test facility; and in the familiar areas of nuclear fuel reprocessing and low-level waste management.

In the sciences our major facilities and unique capabilities are becoming more and more the focus of user-oriented activities. These increase our interaction with outside researchers and broaden not only our contacts, but also our contributions.

Whereas the 1970s saw national policies evolving, I trust that the 1980s will be a time when more decisive actions are taken to meet our energy problems. Hesitation and debate will hopefully be replaced by major new initiatives and commitments to go forward aggressively with key development and demonstration efforts—a strength of ORNL.

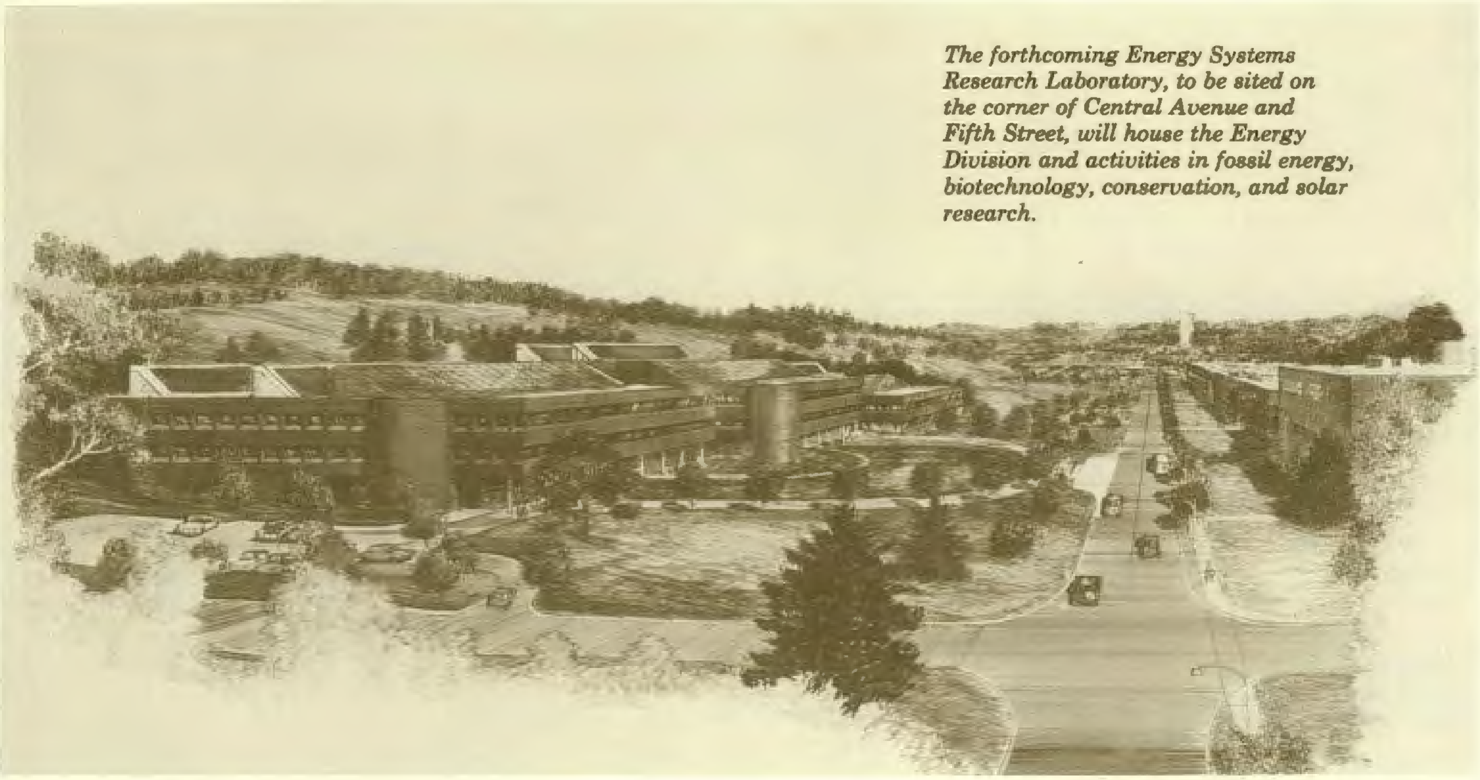
As was announced in the President's budget, we also expect to see construction of ORNL's first major general-purpose facility since the early 1960s, the Energy Systems Research Laboratory. This long-awaited and badly needed addition will house the Energy Division and various activities in fossil energy, conservation, biotechnology, and solar research. It will allow our research staff to work in areas more appropriate to their outstanding accomplishments.

Finally, in this first year of the 1980s, our operating budget will exceed $300 million, thus continuing the steady climb that began in the mid-1970s and indicating once again the confidence that is placed in ORNL.

The Laboratory has fared well recently in anticipating technical problems and being appropriately involved in activities that are most meaningful for attacking the nation's energy problems. However, in contrast with previous years, the President's FY 1981 budget carries the bad news that the budgets for the Liquid-Metal Fast Breeder Reactor (LMFBR) and gas-cooled reactor programs will be seriously cut in the coming year. Not only does this cut represent a major change in energy direction for the country, it could also have serious implications for ORNL.

The now traditional confrontation between Congress and the administration on the Clinch River Breeder Reactor has been extended to the heretofore-protected LMFBR base technology program and associated reprocessing as well as to the gas-cooled reactor development. Whereas the impasse between Congress and the administration only indirectly affected ORNL before, this year we will be caught in the midst of that debate. Major uncertainties will probably persist until September, and, although I have every hope that Congress will restore the original DOE request, this will be a time of uncertainty for us all and a time for contingency planning.

Already, through our institutional planning effort, many of you have been involved in defining and



The forthcoming Energy Systems Research Laboratory, to be sited on the corner of Central Avenue and Fifth Street, will house the Energy Division and activities in fossil energy, biotechnology, conservation, and solar research.

developing some of the major directions our programs will be taking in the 1980s. I also recommend that you read the brief staff version of our long-range plan, *ORNL Trends and Balances, 1980–1985.*

ORNL as a Consultant

The primary theme that I have chosen for this year's address is "ORNL as a consultant." This role is, in fact, a multiplicity of roles that have been highly visible and unusually important in 1979. These activities reflect the pattern of increasing outside interaction, which has become so important to our work.

Consultant activity is only one of a growing number of bridges between our staff and what usually is referred to as "the real world." (I only hope that ours is not all that unreal!) The Laboratory's demonstrated technical strength and leadership, coupled with its reputation for being able to respond promptly, creatively, and objectively when called upon, have created numerous opportunities to work with others and to solve important problems.

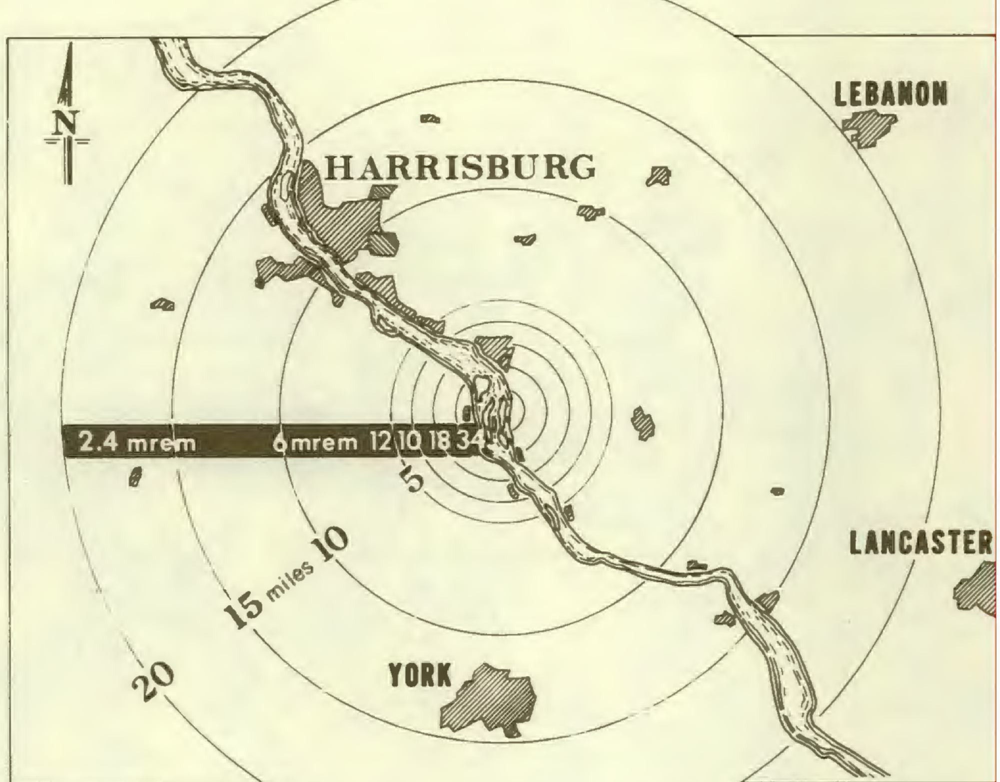
Three Mile Island. The events at TMI are an outstanding example of this role. More than 75 staff members, as listed in the fall issue of the ORNL *Review,* were involved directly at the site and in technical support and analytical roles here. The newspapers and the *Review* have reported in detail on various facets of that involvement as well as on our contribution to the Presidential Commission on TMI.

As we will see, ORNL analyses and problem solving have contributed significantly to the recovery from last year's accident. I firmly believe that the many lessons learned will put nuclear power plant operation and the public acceptance of nuclear energy on a much firmer and more realistic basis for the future.

Although a persistent theme of the post-TMI debate has been what is wrong with the nuclear regulatory process, we can see some very clear examples of what is right. Particularly evident is the payoff from the long-term, high-quality R&D that provides the technical foundation for reactor regulation and the capability to respond when things go wrong. Several elements of the ORNL response in this context deserve special mention.

Bob Brooksbank's team from the Chemical Technology Division provided leadership for the difficult task of controlling both liquid and gaseous effluents from TMI-2. The measure of their success was the virtual absence of any detectable ^{131}I, which would have been the principal short-term public health hazard during the period before the reactor was brought to a cold shutdown. Control and cleanup of the 4.5×10^3 m^3 (1.0×10^6 gal) of contaminated water in the reactor, the containment, and the auxiliary building represent a challenge of equal dimensions. Our expertise

Members of the Industrial Safety and Applied Health Physics Division monitored radiation near Three Mile Island.



provided the major input for design of the flow sheets that are now being used to process low-, intermediate-, and high-level radioactive water in a safe and environmentally acceptable manner.

The Analytical Chemistry Division analyzed teaspoon-size samples of water from the TMI primary system and containment to accuracies of parts per billion. Our capability for diverse, detailed, and integrated analyses made ORNL the prime analytical facility to provide data for understanding the accident, assessing its severity, and devising cleanup processes.

A key contribution to achieving a stable condition in the reactor was the application of "noise analysis" techniques by Bob Kryter and Dwayne Frye. These were developed in the Instrumentation and Controls Division and can determine postaccident conditions in the core, particularly boiling in the core, and entrained or trapped gas in the primary system.

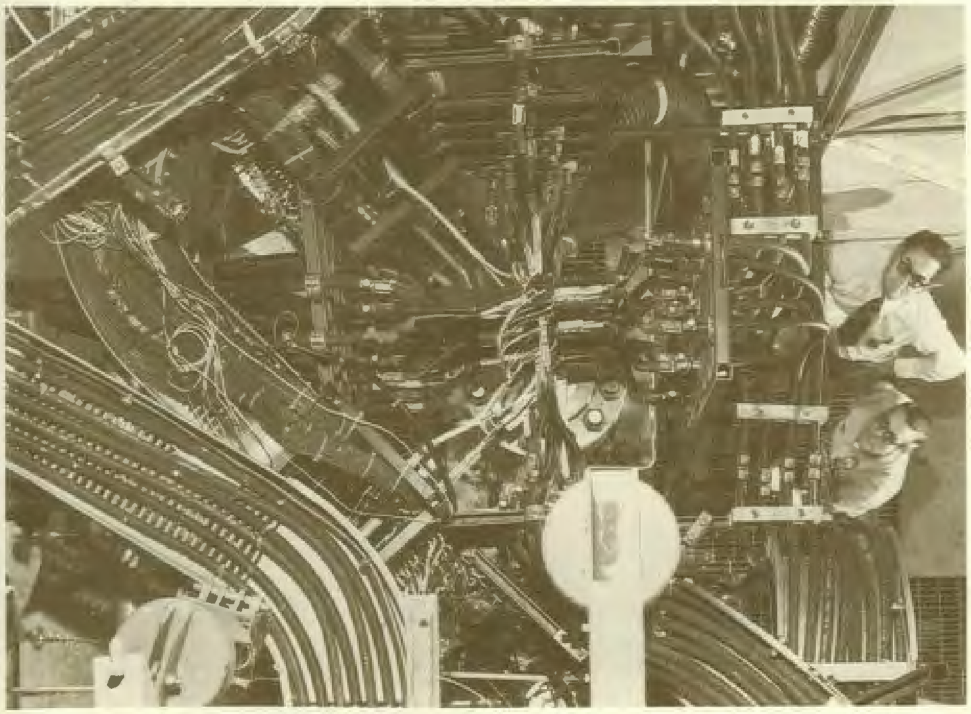
Mario Fontana's group in the Engineering Technology Division provided analyses of the cooling of the disrupted core and calculations that established the limits to which core debris could be cooled under various hypothesized alternative event sequences. Analysis of fuel and cladding effects by members of the Metals and Ceramics and Chemical Technology divisions, led by Dave Hobson, provided data on fission product releases, the amount of hydrogen generated, and characteristics of neutron detectors. Members of the Engineering Physics and Computer Sciences divisions, led by Dave Bartine, provided assistance on shielding questions and radiation effects.

At the request of the Electric Power Research Institute (EPRI), Joel Buchanan of the Nuclear Safety Information Center assisted in analysis of the hydrogen bubble that formed in the reactor pressure vessel; the Chemical Technology Division supported this work with valuable information on hydrogen chemistry and radiolytic gas generation and recombination. In addition to EPRI, other segments of the nuclear industry continue to draw heavily on this consulting assistance.

An Industrial Safety and Applied Health Physics Division group led by Roy Clark provided onsite radiation monitoring and major input to the Kemeny Commission (and Governor Thornberg) on health physics and dosimetry.

Finally, a team under Dave Thomas of the Engineering Technology Division has fabricated a new electrical core for the Thermal-Hydraulic Test Facility that simulates TMI accident conditions. The data from these experiments, involving the most sophisticated core simulator in the United States, will be used by NRC to verify licensing calculations.

More Nuclear Consulting. Before leaving the nuclear area, I will briefly mention several other activities in which we have been involved as consultant. The International Nuclear Fuel Cycle Evaluation, involving more than 50 nations, is now drawing to a close. The evaluation evolved from the Carter Administration's just con-



John Wolfe and Cliff Littleton stand at the foot of a highly sophisticated electrical core fabricated for the Thermal-Hydraulic Test Facility Program. The device has been used to simulate Three Mile Island accident conditions.

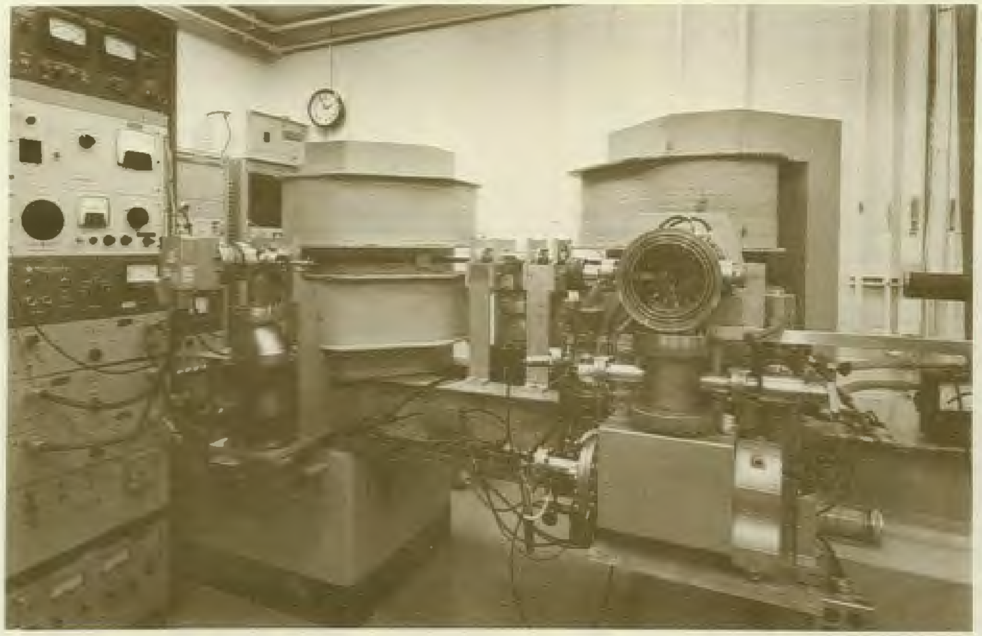
cern with the potential for proliferation of nuclear weapons capabilities; the number of nations producing power from nuclear energy is expected to increase from the present 20 to 40 during the next decade. Not surprisingly, ORNL, with its long tradition in fuel cycle research, has been the source, through Bill Harms and Don Ferguson, of substantial inputs to that evaluation and also to its U.S. counterpart, the Nuclear Alternative Systems Assessment Program.

The ability to safeguard special nuclear materials is at the heart of the proliferation concern. Joel Carter of the Analytical Chemistry Division has developed unique methodology for microsampling and analyzing samples, a procedure that is having an international impact on safeguards analysis and that has been the subject of active consultation involving DOE and the State Department as it is implemented by other nations. The microsampling technique involves acquiring inexpensive samples of ion exchange resin beads that are so tiny that they can be shipped easily and without the usual constraints imposed by high radiation levels. Moreover, microsampling, combined with high-performance mass spectrometric analysis, provides great sensitivity and good accuracy as well as information on isotopic abundances.

A New Standard for Decay Heat. The application of state-of-the-art experimental techniques to solve a practical problem in a timely fashion is evident in an Engineering Physics Division contribution. Kirk Dickens and colleagues shared their research with an American Nuclear Society (ANS) working group that subsequently developed a new standard for decay heat. The ORNL data on ^{235}U, ^{239}Pu, and ^{241}Pu thermal-neutron fission substantially influenced the new ANS standard adopted this past year. The significance of this work is that present licensing requirements for decay heat are shown to be extremely conservative. Indeed, if regulations are now changed in accord with the ORNL data, the result will be increased efficiency of fuel usage.

Recovery of Uranium from Phosphates. Last year *Chemical Engineering* recognized ORNL for development of a process already being used commercially to extend U.S. uranium ore production. This process recovers dissolved uranium as a by-product of the chemical production of phosphoric acid, one of the principal ingredients used in making fertilizer. The 3175 t (3500 tons) of uranium recoverable annually represents a 20% increase in uranium production and a current market value of some $300 million. The two-cycle solvent extraction process, known as DEPA-TOPO, is a joint effort of teams led by Fred Hurst of the Chemistry Division and Dave Crouse of the Chemical Technology Division. Through the researchers' consultation with industry, three large commercial plants are in operation and at least two others are under construction. As with other resource recovery processes, the benefits are both economic and environmental, since valuable uranium is also removed as a radioactive contaminant.

Fossil Fuel Assistance. We turn now to fossil-energy-related consultation. Full implementation of the Strategic Petroleum Reserve, an important cornerstone of the nation's energy policy, will provide a 90-day supply of petroleum that can be drawn upon in the event of another oil embargo. The ORNL Environmental Impacts Program



Microsampling has been made possible in the Analytical Chemistry Division whereby samples of ion exchange resin beads may be analyzed in quantities that can be shipped without extensive radiation shielding.

supplied experts to assist DOE's Source Evaluation Board over a ten-week period in reviewing the ecological and geological aspects of 35 industry proposals for development of the storage complexes. Laboratory aid was also sought in a dramatic problem-solving role when a fire seriously disrupted operation of a salt dome storage cavern in West Hackberry, Louisiana. Bob Gray and Gerry Slaughter of the Metals and Ceramics Division investigated the fire and found that oil leaks in a well head had caused it; they also assessed fire damage to a brine-carrying casing.

As part of the newly acquired DOE Fossil Energy Materials Program, Jim Keiser, Vivian Baylor, and Bob Swindeman of the Metals and Ceramics Division are performing onsite inspections of failed components at coal liquefaction pilot plants. These inspections are followed by detailed metallurgical examination at ORNL to identify the cause of failure. The information is reported to the pilot plant operator and, through DOE and the National Bureau of Standards, to the fossil energy community.

We are providing major support to TVA for its 20-MW(e) pilot and 200-MW(e) demonstration plant projects to test the applicability of fluidized-bed technology in large utility boilers. Materials reliability in the fluidized-bed combustion atmosphere is a key issue that is being addressed by ORNL. Work by John Jones and Bob Holcomb of the Engineering Technology Division also includes coal-feed testing, bed-slumping tests, and sulfur-capture tests using TVA coals and limestones in ORNL's bench-scale facility. We are working closely with TVA on projects ranging from magnetic coal preparation and coal gasification to fuel cells and pumped storage.

In a new and important relationship, DOE's Oak Ridge Operations is drawing on ORNL technical support and consulting services in connection with three large synfuels demonstration projects for which it is responsible—Solvent Refined Coal (SRC) Plants I and II and H-Coal. Our tasks have included evaluation of the environmental and health status of SRC processes, net energy analysis, materials testing and failure analysis, technology reviews, and review of design-related demonstration plant information for SRC-I and SRC-II.

Chuck Boston's Fossil Energy Environmental Project is carried out in collaboration with DOE and its industrial partners on all six major synfuels-from-coal demonstrations now under way. The work involves both technical recommendations for monitoring programs and preparation of environmental impact statements required by the National Environmental Policy Act.

The Life Sciences Synthetic Fuel Program, under Ken Cowser, is providing a model for comprehensive health and environmental assessment of a synfuels demonstration in DOE's Gasifiers in Industry Program, with interactions from the Environmental Protection Agency (EPA) and the National Institute for Occupational Safety and Health. The focus of this effort is a gasifier that will replace the use of fuel oil and that is now beginning operation at the University of Minnesota (Duluth) heating plant. The model will permit DOE and other federal agencies to judge the potential health and environmental impacts and consequent environmental acceptability of further commercialization of low-Btu gasification processes. Eight ORNL divisions support these evaluations, which are specific both to the process and to the site.

Conservation Consulting. Since 1977, Mike Karnitz of the Energy Division and Mitch Olszewski of the Engineering Technology Division, working under Irv Spiewak, have been studying the application of a new hot water district heating

Fred Hurst works in the laboratory where members of the Chemistry and Chemical Technology divisions developed the DEPA-TOPO process for extracting uranium during production of phosphoric acid.

system based on Swedish technology in the Minneapolis–St. Paul metropolitan area. The base heat supply will probably be cogeneration coal power plants, resulting in significant savings of fuel oil and natural gas. The study, conducted cooperatively with state and local governments and Northern States Power, has stimulated the formation of a nonprofit St. Paul District Heating Development Corporation under the leadership of the mayor of St. Paul. The Laboratory will continue its management and consulting role in the first demonstration of this fuel-efficient heating system for a major U.S. metropolitan area. Happily, throughout our conservation program, there are many similar examples of R&D that is moving out of the laboratory and into commercial demonstration or applications of the type described here.

In the industrial sector, a truly enormous potential exists for fuel savings among the four major users of process heat—the steel, glass, aluminum, and cement industries. Use of waste heat recuperation systems has been estimated to offer savings of 2% of U.S. energy usage. Glass furnaces alone account for a potential savings of nearly $1.5 million per day in equivalent oil at $3.81/m^3 ($24/bbl). However, higher efficiencies available through glass furnace recuperation in place of current systems have not been realized, primarily because of technology and materials limitations. Vic Tennery of the Metals and Ceramics Division, under a program initiated by DOE's Office of Industrial Programs, has been evaluating potential refractory structural ceramic materials as candidates for use in glass furnace recuperators with exhaust gas temperatures up to 1370°C. This is significantly above the 980°C limit on present stainless steel recuperators imposed by creep, corrosion, and oxidation. Extensive consultation with potential users in the high-process-heat industries is part of this test program.

The Laboratory's energy-conserving wastewater treatment system, ANFLOW, is leading to active consultation with designers, manufacturers, and potential municipal and industrial users. The next major demonstration will be a 200 m^3/d plant to be built in cooperation with the city of Knoxville. Representatives from several industries, including those for potato processing and meat packing, also have sought our assistance in developing ANFLOW-based technologies for onsite wastewater treatment.

Another environmental control contribution is a development by Chuck Hancher and Brad Patton of the Chemical Technology Division. Their treatment technology, which uses bacteria, was applied to solve a discharge problem at the Portsmouth Gaseous Diffusion Plant, where a nitric acid solvent waste stream would not have met impending EPA standards using present procedures. Portsmouth will use the pilot plant data to design a production unit with a daily capacity of 200 to 1000 kg of nitrous oxide.

We have witnessed the increasing contribution of the social sciences to ORNL programs, particularly in impact assessments of energy facilities. We have also assisted DOE's Office of Energy Research as it considers the need to recognize the social sciences more broadly as basic energy sciences. In this role we have identified research needs and helped link DOE with the social science research community. Another contribution has been to help build impact assessment into the energy policymaking process, as was done by a task force led by Tom Wilbanks toward the formulation of the second National Energy Plan this past year.

Internal Interaction

Although consulting is most frequently considered an interaction with outside organizations, there are also excellent examples of problem solving within the Laboratory where expertise in one area helps to solve problems in another. For example, far-infrared formic acid lasers developed by Don Hutchinson of the Physics Division provided the diagnostic capability used by the Fusion Energy Division to measure plasma electron densities and current profiles on ISX-B. This tool is important in evaluating a number of important plasma properties, including magnetic island formation and rapid plasma density and magnetic field fluctuations.

Loucas Christophorou of the Health and Safety Research Division has developed fast-gas mixtures that make possible the highest known drift velocities in radiation detectors such as ion chambers and proportional counters, enhancing their background rejection capability and increasing the maximum count rate. These fast gases will be used in a new generation of high-sensitivity fission counters being developed by Manfred Kopp and Ken Valentine of the Instrumentation and Controls Division. Other applications are in position-sensitive proportional counters, which require high count rates for efficient detection of synchrotron radiation in small-angle x-ray scattering experiments and in radionuclide imaging and transmission radiography in nuclear medicine.

To me, these examples provide an impressive catalog of the ways in which ORNL as a consultant and a catalyst is dealing with real-life problems and providing real-time solutions.

ORNL metallurgists Bob Gray and Gerry Slaughter were called to West Hackberry, Louisiana, to determine the cause of a fire in a salt dome storage cavern.

Technical Highlights of 1979

Because the preceding discussion began with the technologies, I shall start this accounting of some R&D highlights with the sciences. The first two come from the areas of atomic and nuclear physics.

Channeling Radiation. In 1979, ORNL collaborated in the discovery of channeling radiation, a phenomenon identified recently by *Science News* as one of the top ten

John Jones and Bob Holcomb at ORNL's bench-scale fluidized bed that will be tested by TVA in a demonstration plant.

developments in physics in 1979. Channeling radiation is a stream of intense, directed x rays emitted when particles pass through a crystal. It was demonstrated for the first time at the Electron-Positron Linear Accelerator at Lawrence Livermore Laboratory, where Sheldon Datz of the Chemistry Division and John Barrett of the Solid State Division worked with scientists from Stanford University and Lawrence Livermore Laboratory. The experiments showed that the swift passage of positrons or electrons through open channels in a silicon crystal produced a new kind of x rays. This channeling radiation is unique in that it contains only a very narrow band of energies and is tunable and highly directional. Applications may develop in chemistry, physics, and medicine.

It is fitting that ORNL have a hand in the latest achievements in channeling research because ion channeling in solids was discovered here in the early 1960s. In another development, groups led by Datz and Charlie Moak of the Physics Division used our tandem Van de Graaff accelerator to discover a resonant coherent excitation effect when positive ions stripped of all but one electron (such as N^{6+}) are channeled through silver or gold crystals. This highly excited state provides new insight into the influence of crystal fields on the electronic energy levels of ions penetrating solids and also on the electrons of the solid. For example, as the heavy ion plows through the sea of electrons in the crystal, it creates a wake of increased electron density that trails behind the ion. The negatively charged wake acting on the positive ion generates a new electric field that interacts with the forces exerted by lattice-bound atoms.

Laser-Induced Nuclear Polarization. In another truly fascinating achievement in the world of fast-moving particles, a team of physicists led by Curt Bemis of the Physics Division has developed a new technique for determining the unique size, shape, and other nuclear properties of fission isomers. These isomers are formed when a beam of heavy ions bombards a target of uranium or similar heavy element in an accelerator such as the Oak Ridge Isochronous Cyclotron. Until this technique using lasers was demonstrated by members of the Physics, Analytical Chemistry, and Health and Safety Research divisions, it had been virtually impossible to study any of the 35 known fissioning isomers because these excited nuclei exist for only a thousandth to a billionth of a second before decaying.

In their normal nuclear ground states, nuclei of actinides such as uranium and americium are permanently deformed and resemble footballs, each with one axis about 20% longer than the other. However, it has been thought that fission isomeric states are larger and more deformed. Now, the new ORNL technique, laser-induced nuclear polarization (LINUP), has provided the first direct experimental proof for the large deformations expected for fission isomers. Specifically, LINUP has found that spontaneously fissioning isomers of ^{240}Am are also shaped like footballs—only more elongated, with one axis about twice as long as the other.

The acronym LINUP is very appropriate since the technique uses a laser beam to line up the fleeting nuclei so that they fission preferentially in one direction. The difference between the known frequency for ground-state ^{240}Am and that for the fission isomer is the optical isomer shift, which provides a direct measure of the change of nuclear volume, or deformation.

Pyrolysis in Coal. In the basic energy sciences, the Chemistry Division has several projects under way to facilitate understanding of the chemical reactions underlying coal liquefaction processes. One current study, conducted by Ralph Livingston and Henry Zeldes, examines pyrolysis, which occurs when coal is heated to such high temperatures that it decomposes, breaking down complex polymers into simpler compounds to make liquids. Pyrolysis also produces free radicals, that is, molecules and atoms possessing an odd, unpaired electron. A method to identify free radicals and follow their reactions at high temperatures would provide more information on the type and sequence of events that occur in coal during pyrolysis.

Fortunately, such a method exists using electron spin resonance spectroscopy to detect magnetism caused by the unpaired electron in a free radical. This method promises to be a powerful tool for studying free-radical reactions. Our extension of such studies to fluids at high temperatures has been the first application of this technique to pyrolysis of hydrocarbons that are models for coal. A number of radicals have been positively identified by their spectrum at 500 to 600°C. Examples include the benzyl radical formed by the decomposition of the bibenzyl molecule, a model for weak carbon-carbon bonds in coal. It is noteworthy that the reaction yields toluene and has been found to be reversible.

Complementing these spectroscopic studies is a series of investigations by Marv Poutsma of the Chemistry Division. Kinetic and product analysis methods that also promise to provide clues to what is happening in high-temperature coal reactions are used. One study, for example, has shown that at least ten elementary reactions are required to describe the free-radical decomposition of bibenzyl.

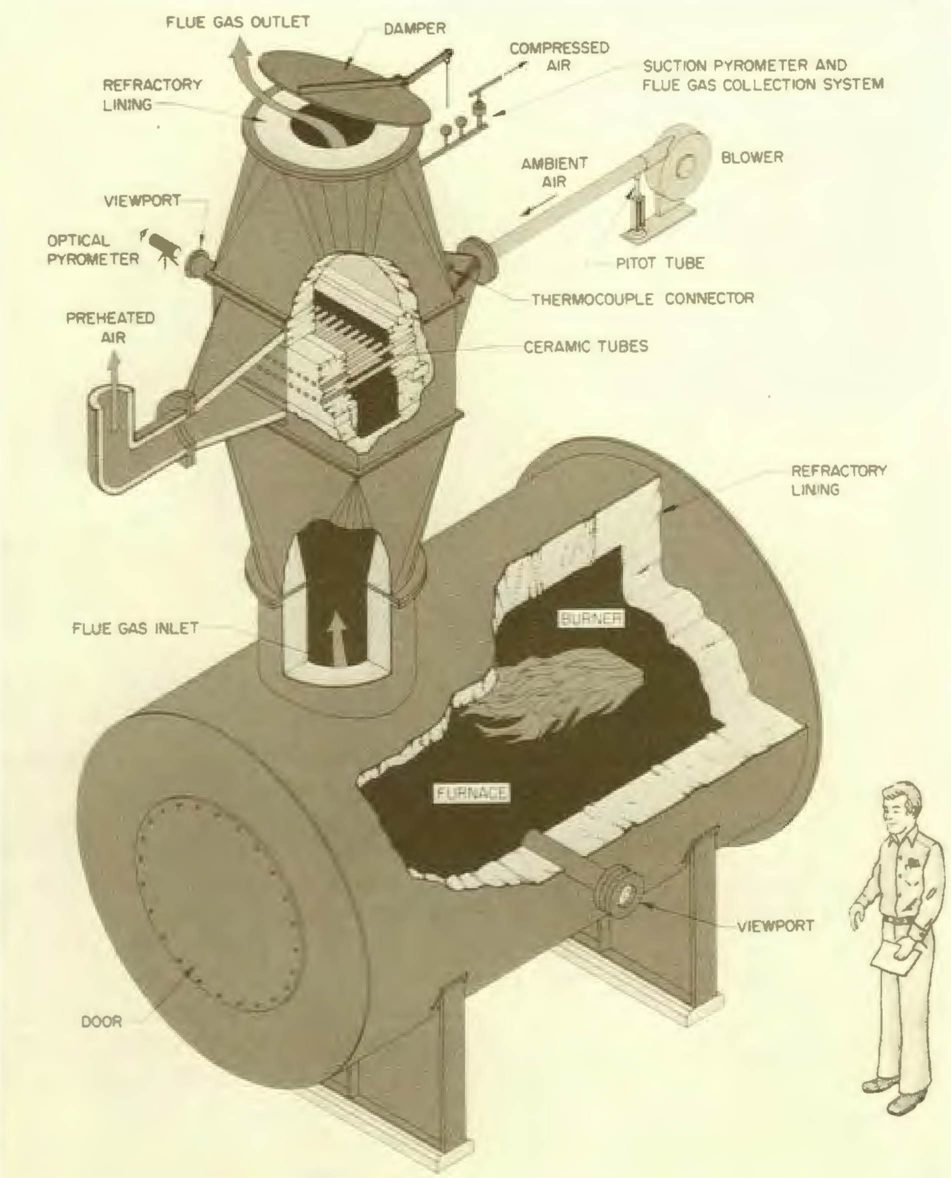
Wilson Pitt at the ORNL-developed wastewater treatment system, ANFLOW, which will be demonstrated soon by the city of Knoxville.

Liquefaction Research. Other surprises have resulted from joint experiments performed by Poutsma and a group of engineers in the advanced technology section of the Chemical Technology Division. Simulating direct coal liquefaction processes, which involve slurrying pulverized coal in a process-derived solvent and heating it under hydrogen pressure at 450°C, the researchers observed organic reactions involving the various functional groups in coal and the process solvent. One discovery, made by John Larsen of the Chemistry Division and also The University of Tennessee, is that of the ability of phenol to liquefy coal in the absence of additional hydrogen. This suggests the possibility of using hydrogen originally present in the coal structure to produce hydrogen-rich liquids for fuel rather than using externally produced hydrogen.

Genetic Repair. In the Biology Division, geneticists led by Walderico Generoso have discovered a phenomenon having important implications for screening studies on chemical mutagens. They found that mouse egg cells are able to repair genetic damage in the sperm that fertilized them and that different genetic strains of mice vary widely in their ability to perform this repair. The findings are particularly important to toxicologists who work with the widely used "dominant lethal" test for mutagen screening. In this test, mutagenicity—the ability to damage chromosomes—is determined by the percentage of embryo deaths after an egg is fertilized with sperm from males that have been treated with the chemical under investigation.

The study suggests that apparently negative results from the dominant lethal test may be the result of the ability of the egg cells to repair damage done to the fertilizing sperm and that the results might be significantly different if another mouse strain were used. The fundamental significance of this discovery is far reaching because for the first time a repair-deficient laboratory mammal is available for studying repair processes. The discovery could also provide a new understanding of the important relationship between repair processes and mutagenesis, teratogenesis (the production of a highly abnormal fetus), and carcinogenesis. Because cancer causes are not only elusive but unavoidable, the understanding of repair is truly important.

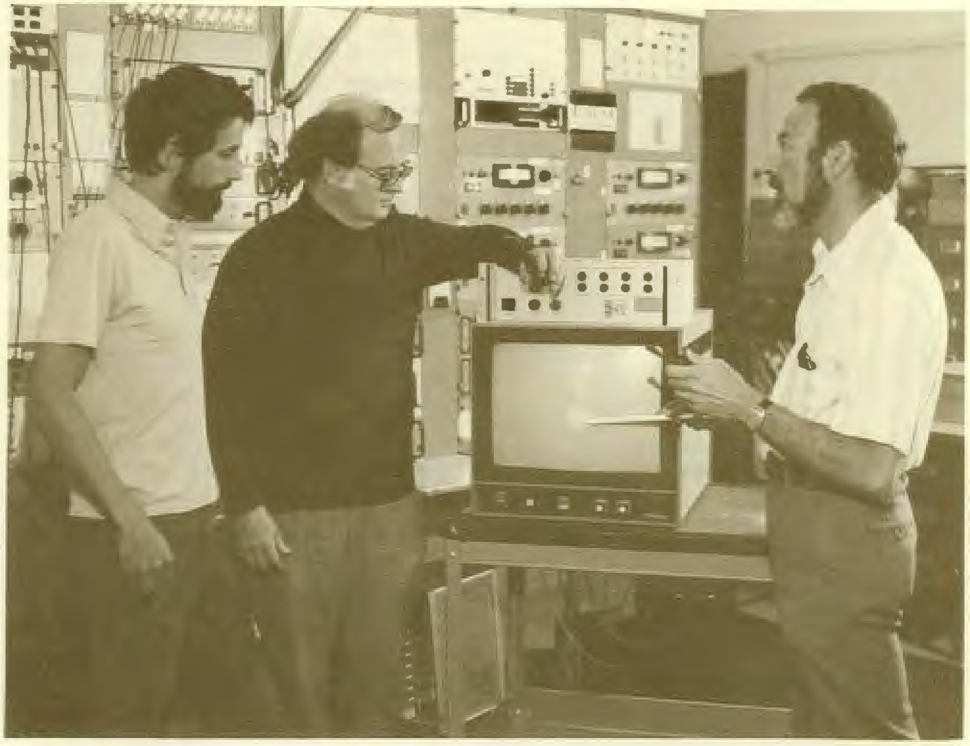
New Mutagen. Another Biology Division discovery by Bill Russell and colleagues has received wide attention. This is a laboratory chemical called ENU, which is by far the most powerful mutagen yet discovered. Tests reported by



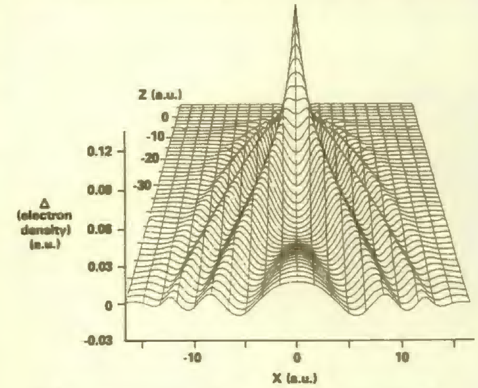
Ceramic Recuperator Analysis Facility used at ORNL for experimental testing of structural ceramic heat exchanger materials in fossil fuel combustion environments at temperatures up to 1250°C. Results are used to determine fuel-ash components damaging to state-of-the-art candidate ceramics and to develop advanced materials for construction of very high-temperature heat exchangers for use in highly contaminated environments.

Russell in the November 1979 *Proceedings of the National Academy of Sciences* showed that the mutation rate with ENU was five times that of the most effective acute dose of x rays (600 R). The ENU rate was 15 times that obtained with procarbazine, the most mutagenic chemical previously known in the mouse, and 87 times that of naturally occurring mutations in mice. From a basic research standpoint, this development provides a foundation for further research into the actual nature of mutation induction in mammals because ENU can now serve as a model compound in exploring the effect of such factors as dose response, dose fractionation, sex, and cell stage on the mutagenic action of a chemical.

Hydrogen and Oxygen Produced in Photosynthesis. In the extended energy debate no one yet has suggested that green plants may be the answer. However, Eli Greenbaum of the Chemical Technology Division has demonstrated the simultaneous production of hydrogen and oxygen by photosynthesis, representing an intriguing way to capture and convert solar energy into stored chemical free energy. The experiments involve the use of a cell-free system composed of isolated chloroplasts (spinach) as the starting material. Noteworthy in this development is that all three of the known potential direct photosynthetic water-splitting systems [blue-green algae, green algae, and the chloroplast-ferrodoxin-hydrogenase (CFH) system] have now been shown to photoproduce molecular hydrogen and oxygen for prolonged periods. The ORNL work is believed to be the first measurement of simultaneous photoproduction of hydrogen and oxygen in the CFH system. The data suggest that this system is capable of performing true biophotolysis of water. Although currently observed rates of oxygen and hydrogen production are too low to be of practical interest, it is believed that they can be improved significantly by additional study. The ideal photosynthetic water-splitting system would perform hydrogenic photosynthesis in much the same way that normal photosynthesis is performed. Hydrogen and oxygen would be evolved continuously in a ratio of 2:1 upon illumination with sunlight. This is a challenging problem because it means taking over the photochemical machinery of photosynthesis in a way that provides no obvious



An electron-positron linear accelerator at Lawrence Livermore Laboratory successfully demonstrated channeling radiation last year at the hands of a team that included Sheldon Datz and John Barrett. Here, Datz (center) discusses their achievement with California colleagues.



A heavy positive ion creates a wake of electron density as it moves through a solid (in this case, away from the viewer). Oakley Crawford and Rufus Ritchie have shown that this wake has an appreciable effect on the electronic energy levels of the ion.

metabolic benefit to the organism. Much fundamental information still is needed on the physics and chemistry of oxygen evolution, the movement of electrons through the electron transport chain linking the two systems, and the manner in which these electrons are coupled to the hydrogenase enzyme.

Long-Term Waste Storage. In the nuclear area, the need for even better stable long-term storage forms to isolate and immobilize radioactive wastes continues to attract high-quality and imaginative R&D. Many candidate forms and processes are being considered in a national program to which ORNL is an important contributor. The development of the ceramic-metal (cermet) form as a spin-off of our isotope target fabrication activity in the Solid State Division was described last year. This year, the Metals and Ceramics Division reported another potentially important spin-off from an established program. This was the application by a group led by Jack Lackey of its "sol-gel" technology, developed over nearly 20 years for reactor fuel fabrication, to the fixation of radioactive waste in either glass or crystalline forms. Materials typically sinter to strong spheres of minimum porosity at temperatures several hundred degrees lower than those required for conventional powder processes. Our preparation of Synroc pellets indicates that dense waste forms can be produced without the need for hot pressing or melting, which would be more complex for remote operation.

Another promising host material being developed by a team in the Chemical Technology Division led by John Moore involves the fixation of waste in concrete, in reality a low-temperature ceramic. This process could also be considered a spin-off—in this case, from our use of cementitious grouts in the hydrofracture process to fix and permanently dispose of locally generated low- and intermediate-level waste solutions. The group found that reasonably hard, durable solids containing up to 25 wt % simulated radioactive sludge can be made by subjecting the cementitious mixtures to temperatures from 100 to 250°C and pressures up to 4.14×10^6 Pa (600 psi) for 24 h. In actual practice the thermal power of the incorporated waste would be used to help attain the temperature and pressure required during hardening. The advantage of these materials appears to be ease of use and low costs.

Permanent Waste Isolation. On still another new frontier of waste form development, researchers in the Solid State, Chemistry, Analytical Chemistry, and Metals and Ceramics divisions have collaborated on a potential candidate for permanently isolating the longest-lived nuclear wastes. Working under Lynn Boatner at the Transuranium Research Laboratory, they have synthesized a mineral called monazite, a crystalline material found in nature (frequently a host for thorium and uranium) and known to be stable for as long as a billion years. The studies show that

Ralph Livingston, pictured, and Henry Zeldes have been studying the mechanism underlying coal pyrolysis.

Waldy Generoso discovered a genetic repair mechanism in female germ cells which acts on damage in the sperm.

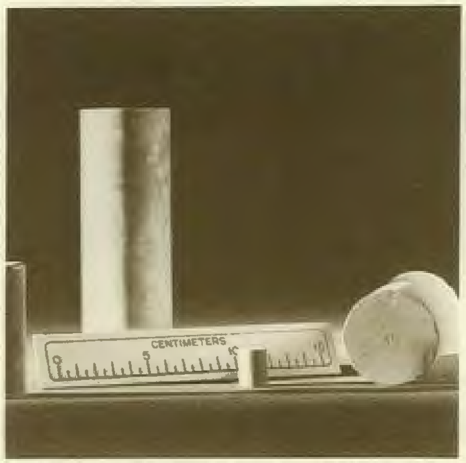
actinide ions such as Pu, Am, Cm, and U can be incorporated into the synthetic monazite. Furthermore, the actinide-spiked monazites grown in the laboratory are as resistant to leaching as the natural crystals. These results suggest that encapsulating nuclear wastes in synthetic monazites and embedding them in a natural rock formation such as granite would effectively isolate the longest-lived radioactive materials from the human environment.

Although it would not be practical to grow spiked crystals in making actual waste forms, it appears that synthetic monazites can be formed from reactor fuel wastes by adding only small amounts of phosphate chemicals and calcining the mixture because rare-earth oxides are already present in spent reactor fuel at relatively high concentrations. Further studies are planned to check the feasibility of this still very experimental approach.

Materials Development. It is a rare year when the Metals and Ceramics Division does not come forth with an important new materials development and this year is no exception. One of these is a new 9 Cr–1 Mo ferritic steel alloy considered to be a potential replacement for higher-cost, higher-chromium stainless steel alloys currently used for superheaters in coal-fired plants. Successful demonstration of this material would offer the advantage of lowering our dependence on unstable foreign sources of chromium. This alloy has excellent resistance to stress corrosion and thermal shock. In addition, an all-ferritic-steel alloy system would eliminate the need for the difficult transition weld joints that lessen system reliability. Until now, such readily fabricable alloys have generally had lower strengths than austenitic steels at 500 to 600°C and hence their use has been restricted. The modified 9 Cr–1 Mo steel developed by ORNL's Vinod Sikka, together with C. T. Ward in Combustion Engineering of Chattanooga, has good ductility and high-temperature strength comparable to type 304 stainless steel. Minor alloying elements such as tin, niobium, and vanadium impart the unique properties of the new material, which is now being prepared for testing in a TVA fossil plant superheater.

The Metals and Ceramics Division has also reported significant progress in developing alternative hard materials for cutting, grinding, and wear-resistant applications that are not dependent on scarce foreign sources of supply. The usual material is cobalt-bonded tungsten carbide, but cobalt is now classed as strategic and unreliably available. Work by Wayne Clark and C. F. Yen has shown that titanium diboride, bonded by nickel, offers erosion resistance comparable to that of cobalt-bonded tungsten carbide and uses materials available in the United States. The Y-12 Plant has

Bill Russell heads the team that discovered ENU, the most powerful mutagen known to man.



A group led by John Moore has discovered that radioactive sludge can be fixed in cementitious grout with relative stability under high pressure and temperature. The sample on the right, with the hairline crack, was tested at 900°C for 24 h.

confirmed its desirable characteristics for machine-tool applications.

Fusion Energy Research. The fusion program continues its recent string of successes. Based on the recent advances here and elsewhere, there appears to be growing support by the scientists and in both the administration and Congress for accelerating the pace of this program. Much of that discussion now centers on the timetable for the Engineering Test Facility (ETF), which would bridge the gap between near-term devices such as the Tokamak Fusion Test Reactor at Princeton and a long-term engineering prototype reactor, the final step before construction of a commercial demonstration reactor. Early in 1979 ORNL's selection as host site for the ETF Design Center was announced. The ETF organization currently has a staff of 20 people, most of them from industry. Its task will be to establish technical requirements for the major components of a prototype fusion reactor and to develop its design in sufficient detail to support eventual authorization of the ETF project. The location of the design center here provides us with a very active role in this key development and demonstrates not only the breadth and quality of our fusion program, but also our ability to organize, coordinate, and conduct a national design effort crucial to the future of fusion.

This was also a year of substantial achievement in the ELMO Bumpy Torus (EBT) Program. The EBT, invented at ORNL, is now a leading alternative to tokamaks for achieving power from fusion. A significant milestone has been the design effort this year culminating in acceptance of a reference design for the proof-of-principle experiment. Under Laboratory direction this activity will be the first actual cooperative enterprise in which industry has been given almost complete responsibility for design, fabrication, and installation. The Department of Energy has assigned ORNL overall management responsibility for the project and for technical coordination of the national EBT program.

The outstanding fusion R&D achievement occurred with the injection of up to 1 MW of neutral beam power into ISX-B, our current tokamak experiment. This injection resulted in central values of beta—the ratio of plasma pressure to magnetic field pressure—of up to 8%. Plasma pressure may be taken as a measure of the fusion power produced, whereas magnetic pressure is a measure of the power usage and cost. Thus the higher the value of beta, the more economical a fusion reactor will be. So far, no saturation of beta with beam power or decrease in confinement time has been observed. This is significant because the values of beta achieved are even in excess of those that would be expected for the onset of an instability predicted by ideal magnetohydrodynamic theory. By increasing neutral beam power further and changing the shape of the plasma, we hope to achieve

Ron Baldwin steadies a commercially cast valve body as a crane moves it over his head, while Vinod Sikka holds a centrifugally cast, cold pilgered boiler tube made for use in the TVA power plant at Kingston. Both items are made of modified 9 Cr–1 Mo alloy, as are the massive ingots shown.

even higher betas with ISX-B during the next two years. Assuming that there are no instabilities, it appears that the projected beta should shortly reach the reactor-relevant regime, which is only a factor of 2 to 4 from present achievements.

Summary and Outlook

Scientifically and technically, 1979 has been another excellent year for ORNL staff. As always in the State of the Laboratory address, I have only been able to give a few examples of those achievements from among many outstanding contributions. I have emphasized the continuing role of ORNL as a consultant and catalyst, both to outside organizations and within our own structure. The examples were taken from a year that seemed particularly active.

There were, of course, many other activities during this year. We dedicated the Environmental Sciences Laboratory and applied the finishing touches to that first new major programmatic laboratory and office space in many years for ORNL. We watched with eager anticipation as the final touches were also applied to the Holifield Heavy-Ion Research Facility and look forward in the next few months to its operation. We saw the groundbreaking for a companion facility, the Joint Institute for Heavy-Ion Research, the earth covering of which will demonstrate an innovative approach to energy conservation. Here ORNL is a partner with Vanderbilt and The University of Tennessee. We have seen the National Science Foundation neutron scattering facility come into being and begin shakedown operation. New waste facilities have been completed, and a steam plant that releases us from dependence on oil and natural gas and frees those resources for other uses is now in operation.

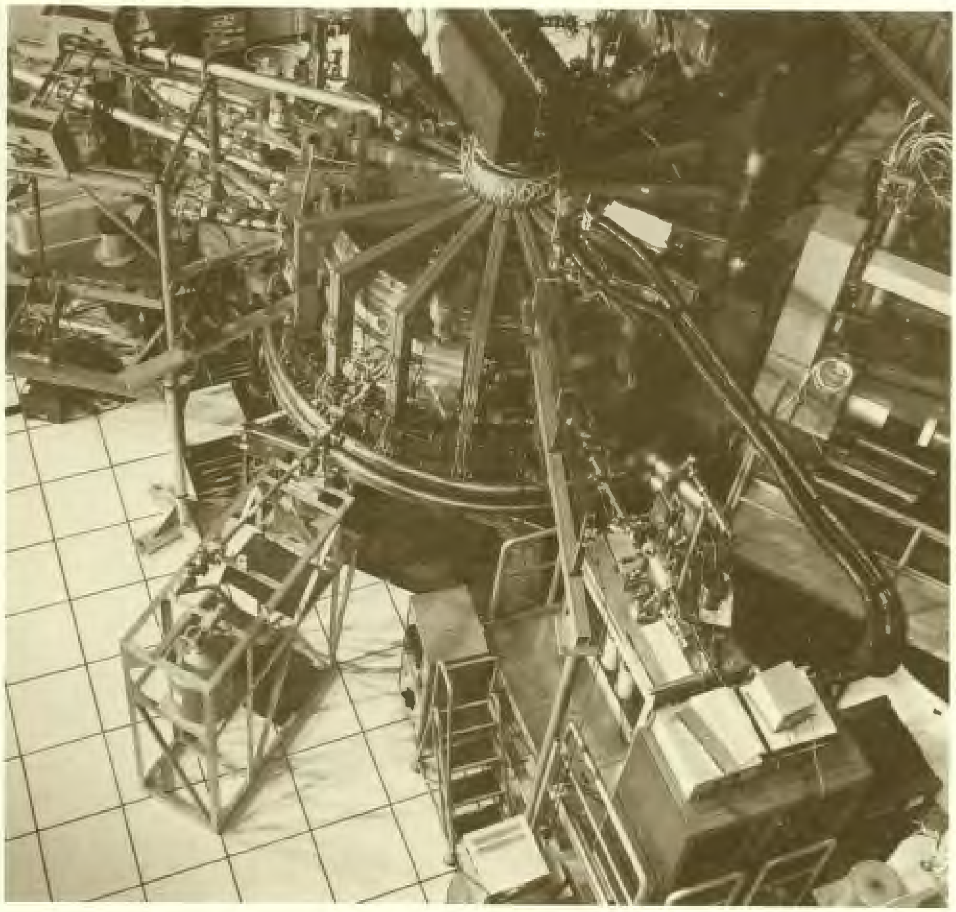
Ruth M. Clusen, Assistant DOE Secretary for Environmental and Biological Sciences, visited ORNL in 1979 to speak at the dedication of the new Environmental Sciences Laboratory.

In addition to all that I have discussed, there is still another very significant factor, one that is not often mentioned explicitly but that is absolutely vital. That is the role of our service and support staff, whose members contributed in a crucial way to all of the achievements that I have mentioned and to many others. Their innovations, ideas, techniques, and devotion have contributed and add up jointly to the teamwork necessary for achievement. I have been reminded of their role not only by those individuals currently at the Laboratory who come up to me and mention the contributions of that supporting staff, but also by those who have left the Laboratory. In reminiscing they mention how often they appreciated the work and contributions of those people, how easy it was to get so much done in so short a time, and what a unique asset they are to the Laboratory. To these many people we owe our thanks again this year.

I mentioned earlier, but it is important to reiterate, the significant contributions made by many in establishing programs and directions that were nontraditional at ORNL but that are now part of the fabric of the Laboratory. Recognition is accorded those who tried so hard and ultimately succeeded in gaining the confidence for these activities. In many areas sponsors were wary of ORNL's possible involvement but, after working with us for a while, became our strong supporters.

Fortunately, this year there has been a reversal in the trend of reduced support for basic sciences within DOE. Last year the President's budget for the first time brought a meaningful increase in the basic physical sciences. For FY 1981 we see a similar reversal in the downward trend for the life sciences. In fact, there will be relative growth for the basic biological sciences for the first time in many years.

We see continuing growth in the federal government's investment in R&D related to energy not only in absolute value compared with all other nations, but also as an increase in the percentage of the gross national product devoted to



Tokamak experiment ISX-B demonstrated the success of neutral beam injection with new high values of beta—the ratio of plasma pressure to magnetic field pressure, or the measure of fusion reactor efficiency.

The Joint Institute for Heavy-Ion Research will be housed in an energy-conserving building of innovative design.

energy R&D. The Laboratory has certainly shared in and contributed toward that investment.

However, at the same time, we are impacted more directly by the politics of energy R&D, a trend that has been going on for the last few years. Perhaps this is an inevitable consequence of the pervasive nature of the energy problem and the constituencies built up to advocate different energy solutions. It is nonetheless disquieting to be part of a system that, as a result, must vacillate and be subject to turmoil. This is not conducive to excellence in research, nor does it result in an atmosphere in which the best thinking can be done.

Finally, each year brings me new excitement in the discoveries that represent the outstanding work of the Laboratory. I hope that each of you similarly can share not only in the excitement of your own work, but also in that of your colleagues as it is published in articles and given other forms of recognition. Oak Ridge National Laboratory can remain great only by continuing its committal to excellence and to the choice of important and crucial problems for research. Again this year, I find enormous reason to be proud of our past accomplishments and to be optimistic for the future. ornl

BOOKS

Computer Lib, *by Theodor Nelson; distributed by the author, 702 S. Michigan, South Bend, IN 46618 (paperback, 5th printing, 1974). A two-in-one book, 69 and 59 pages respectively; $7.00. (Reviewed by David E. Fields, Health and Safety Research Division.)*

Theodor Nelson has worked and played with computers for much of his life, and *Computer Lib* is his overview of computer applications. The book is general in content and global in scope, examining the entire range of machine sizes and applications from computer graphics to services purchased from one's local franchised computer network outlet. Nelson explains the latter possibilities and his view of just what the local computer outlet should be in fascinating detail.

An unusual publication, *Computer Lib* is actually one work that comprises two titles: "Computer Lib" and "Dream Machines." It resembles the dual sci-fi pocket books of yesteryear (except for its size, an unwieldy 27 × 35 cm) in that the first manuscript starts on the front cover and is read toward the back, whereas the second starts on the back cover and is read toward the front, the two meeting in the middle. Each offering is printed upside down with respect to the other, so both are perfectly legible.

More like magazines than books, "Computer Lib" and "Dream Machines" each comprise a series of vignettes about computer-related topics. The topics are occasionally depicted by an annotated diagram but more often take the form of printed copy ranging from a few lines to as much as two pages. The text is liberally cross-referenced, as one would expect from an original thinker, which the author obviously is. One of his dreams is to implement a truly elegant computer system called the Xanadu Machine, which would permit communication in "hyper-text."

Hyper-text in its simplest form resembles a linearly organized piece of writing such as this review but with added lines from various sentence elements linked to words and phrases of a parallel text on an adjacent page.* For hyper-text to really work, one needs a more powerful pointer capability, and that is where the computer becomes useful. I have written letters in my own version of hyper-text, with lines linking digressions and parallel thoughts, but unfortunately paper is not the proper medium.

This book does have deficiencies, the most glaring of which is the lack of an index. The reader suffers a second loss in encountering numerous penned-in changes and deletions, not to mention the tiny five-point type. The overall impression is that this was perhaps an experimental publication that was recognized by its readers for the valuable resource it truly is only after it had been released. But why not "clean it up" in subsequent printings? It is possible that Nelson (1) is publishing the books himself and (2) suspects, probably correctly, that the books are reaching his intended audience; he therefore sees no need for improvements. If this is so, however, I would be surprised because he is a former member of the senior staff of Harcourt Brace Jovanovich, Inc., and consultant to Bell Telephone Laboratories and Columbia Broadcasting System laboratories.

Nelson writes well, often in a folksy style. His books, supposedly written for the layman, are full of surprises, and I recommend them to anyone who is interested in gaining perspective on the subject.

*If the advantages of such a scheme are not immediately apparent, consider the value of footnotes.

In the accompanying article, C. S. Lisser states the case for quality assurance (QA). In 1976 he became the Laboratory's QA auditor after 21 years in the Instrumentation and Controls Division as a development and project engineer. In his present capacity he audits the QA programs of each of the Laboratory's divisions and support organizations, counsels divisional QA coordinators, offers QA orientation to new employees, and conducts appropriate courses on the subject at all four Nuclear Division plants. To Lisser, QA is a way of formalizing the standard of excellence for which the Laboratory has long been known.

With All Deliberate Assurance

QA at ORNL

By C. S. LISSER

We cannot prove that good maintenance prevents automobile accidents, nor can we prove that applying quality assurance (QA) keeps our work trouble-free. But in both cases we rightfully suspect that we improve our chances by looking ahead. The Laboratory's QA Program is our way of very deliberately seeking freedom from doubt. The planning, the double checking, the testing, and the proving are all part of ensuring the quality of our work.

Simply put, QA is the systematic search for quality. If we had the unremitting drive for excellence imputed to old-time Swiss clockmakers, we would not need such systematic assurance. But we must admit that the clockmaker's search for perfection has been tempered somewhat in our civilization. We, too, are devoted to our work; but it does compete with jogging, chamber music, kids, boats, lawns, and cabins.

Our work has become more intricate; our deadlines, more demanding; our research, less simple. To ensure quality, we must carefully plan our approach, follow that plan, and verify the data. The tool for this is the QA Program. At ORNL, as in other institutions, this program is a collection of procedures to direct a disciplined handling of work.

Quality assurance is employed in scientific and technical work, in space exploration, in food production, in medicine, and in most industries. Although it has been practiced in all industrialized countries, Japan was the first to make it a national policy. Before the war, cameras and optics traditionally came from Germany, watches were made in Switzerland,

... today the Laboratory is a respected leader in the judicious application of QA to research and development work.

motorcycles came from Britain, and cars were built in the United States. Now the Japanese make all these products, and we expect high quality when we buy them.

The Laboratory has been formally participating in a QA program for a decade. The Atomic Energy Commission first directed us to enter the field, primarily to ensure the quality of work done for the Division of Reactor Development and Technology. Since then other sponsoring agencies have joined the movement, and today the Laboratory is a respected leader in the judicious application of QA to research and development work.

Judicious is the operative word. Mindless conformity to regulations is self-defeating. We tailor the implementation of the ORNL QA Program to the specific work. No bench top assembly of glassware is, *prima facie*, a candidate for QA procedures; nor is classical, disciplined QA adaptable to paper studies. On the other hand, ORNL staff members are expected to adopt all reasonable measures to ensure that work is done well, correctly, repeatably, and reportably.

Keeping the progress of work unimpaired, both with respect to delays imposed by procedures and those imposed by false starts and failures is the goal of QA. How many false starts or failures QA prevents we cannot say with certainty. We do total the costs of fixing reported failures. What we cannot show is the amount of money we have saved because of the QA Program.

We could probably say that if we had not practiced QA for the last ten years, Washington would have channeled much less work here. Without QA we might have encountered environmental problems like the Paducah oil spill into the sewers—except that our spill might have been radioactive. The fact is, we do not know what problems we have escaped through the use of QA as a technical management tool.

Quality assurance must have always been a self-governing feature of man's work. Arrows and axes either worked well or the developer paid the supreme penalty for slipshod work. Cave shelters were either designed for efficient ventilation or had to be abandoned posthaste in the morning. The tall Stonehenge sighting ports probably took their toll among careless stone setters, and early pottery must have been a risky export line.

Doctrinal QA came with the industrial revolution. People began to check what had been produced in cottage industry and on the farm to make sure that the product met the needs. Improved communications led others to publish only doubly checked work as defense against immediate and heated refutations by colleagues elsewhere.

Today we have arrived at the concept of QA with the clearly stated belief that one must plan the whole job and that this planning includes surveying possible unexpected failures and means for their prevention. Quality assurance is trying to ensure that what is developed and designed is what was intended and that the product will answer the need.

However, we must bear in mind that a product is not necessarily an object. At ORNL the scientist turns out a data product, the engineer translates research into development and design, the craftsman builds the engineered

... most research and development installations have QA programs ...

units, and administrators and other personnel produce the support base that is so vital in our civilization. Is it reasonable to apply the concept of formal QA to our work at ORNL? Absolutely. In fact, most research and development installations have QA programs, as do service industries where no manufactured product is involved, such as the health care industry and even the tourist industry.

The German Quality Society publishes a periodical in which I found an interesting article about QA applied to tourism. The interviewed head of the travel bureau extolled QA in glowing terms and cited standard QA procedures employed in his industry. "Quality," he said, in free translation, "is fitness for intended use. That applies to services as well as to products. Travel is a pure service industry, and we apply QA successfully." Much of the motivation for using the technique probably comes from lawsuits and damage awards filed against travel agents, airlines, hotels, etc., when services fail to measure up to promises. Regardless of the incentive, these people show that they can successfully plan their services, fit clients to destinations, and have alternative action plans to take care of unexpected failures.

The travel industry uses *check-listen* surveys that are filled out by scouts sent to reconnoiter conditions such as the quality of the beaches, the fitness of the town for different age groups, and the distance from the hotel to the entertainment centers. Other procedures instruct the staff how to react to specific problems and procure alternatives and even how to take care of a *krisen-notfall* (when everything goes sour). A hundred thousand clients a year write in to laud, inform, or complain, and their comments are punctiliously fed into the computer data packages for each tour, city, hotel, and time of year.

As for the health care professionals, it is my guess that they lead all other professionals in the use of QA techniques. They are perhaps more exposed to legal penalties for uncertain quality, but still they have identified the need for and do use QA. As a report published by the Veterans Administration Research Hospital in Chicago puts it: "Health professionals have enjoyed considerable authority and independence. This autonomy, however, does not preclude professional and institutional responsibility for quality."

Our approach to QA at ORNL is simple: Whenever a job of any size is under consideration, we look at what we are about to do and evaluate whether normal good practice will get the job done right the first time. The evaluative look is recorded on a one-page QA assessment form. If the form concludes that good practice will not necessarily ensure an excellent chance of success, then we make a QA plan to spell out what "shoals" we foresee and means for avoiding them. Then, having carefully planned our action, we make sure that the plan is followed. If the plan does not work, we report the failure to ensure that the same mistake will not be made again. The ORNL staff is expected to "look before leaping." This makes good sense, and the ORNL QA Program requires it. ornl

information meeting highlights

HEALTH AND SAFETY RESEARCH.

March 5 and 6

Multiphoton Ionization Spectroscopy

A high-powered dye laser tightly focused on target molecules can ionize the molecules and, in many cases, blow them into multiple fragments. For example, if visible light is tightly focused into benzene vapor, the ions resulting from bombardment of this carbon-hydrogen compound (C_6H_6) are H^+, C^+, and C_2^+. The ion and electron fragments can be detected by a mass spectrometer, an electron multiplier, or a proportional counter.

Bob Compton and his colleagues in the Health and Safety Research Division (HASRD) have been bombarding gas molecules with laser photons whose combined energy strips away the loosely bound outer electrons of the target gas. This technique, called multiphoton ionization (MPI), permits the determination of previously unknown molecular energy levels. The technique can also use visible light from the laser to excite the target gas into the vacuum ultraviolet region of the spectrum, a region of invisible light that has a shorter wavelength than the visible spectrum and can only be used in a vacuum because it would be totally absorbed by air. According to Compton, MPI appears to be the most selective analytical technique for identifying and quantifying pollutants because of its ability to differentiate among isomers (molecules that differ in structure but not in mass). The method is expected to be useful in ^{14}C dating and in many other areas of mass spectrometry.

Compton, Ashley Williamson (a former postdoctoral student from the California Institute of Technology), and John Miller have used pulsed dye lasers to photoionize the rare gases xenon, krypton, and argon as well as gaseous organic compounds such as benzene, methyl iodide, pyrrole, furan, naphthalene, and uranocene. At sufficiently high power levels, a laser beam of any wavelength will ionize a gas, but the ionization signal will be enhanced if the photons are in resonance with one or more of the gas energy levels. That is, if the photon has the exact energy (wavelength) required to raise the outer electron of an atom or a molecule from a lower to a higher energy level, the eventual ionization of the atom or molecule will be resonantly enhanced. A strong ionization signal in the target gas indicates that the laser is properly tuned and that the photons are in resonance.

This information on the energy absorption spectra of the atom or molecule adds to the scientific understanding of the properties and structure of the species. In particular, energy levels that cannot be absorbed in one-photon processes may be allowed in multiple-photon absorption. Scientists have mapped the absorption spectra for single photons in various atoms and molecules for the last 50 years. However, molecules can be excited to other energy levels by absorption of two photons simultaneously. In fact, according to rigid selection rules, some energy states can be achieved by absorption of two photons but not one, and vice versa. If it is possible to use photons having two or more different wavelengths so that the photons are in resonance with two or more energy levels of the gas, the ionization signal is greatly enhanced and the resulting spectra are simplified. Williamson and Compton pioneered the two-laser technique and applied it to the iodine molecule. The optical spectrum of molecular iodine is exceedingly complex, and molecular spectroscopists have spent lifetimes interpreting the spectra of I_2. However, the I_2 spectrum is greatly simplified when two laser photons are in resonance with the I_2 energy levels—that is, when one photon is tuned to a particular vibrational and rotational level of iodine and the other is tuned in the region of 5×10^{-3} m (5000 Å).

Compton, Miller, Ada Carter, and Peter Kruit (a visiting scientist from the FOM Institute in Amsterdam) have pioneered a new technique called MPI photoelectron spectroscopy (MPI-PES). Tom Carlson and Manfred Krause of the Chemistry Division are well known in the area of conventional photoelectron spectroscopy (PES), a technique whereby photons from a helium light source are used to expel electrons from a target gas. An electron energy analyzer measures the range of kinetic energies of ejected electrons. Compton and his colleagues have studied the kinetic energies of electrons knocked loose by multiple photons for the first time. Says he: "We're finding some interesting differences in the kinetic energy spectra of electrons produced by MPI as opposed to single-photon ionization."

Perhaps the most fascinating finding of MPI studies at ORNL has been the observation of MPI as a function of gas pressure. P. M. Johnson at the State University of New York reported that MPI had not enabled him to detect the lowest known resonance level of xenon. He did, however, observe strong ionization signals when he tuned his laser to higher energy levels. His studies of xenon were carried out at pressures above 133 Pa (1 torr). However, when Miller and Compton tried five-photon ionization on xenon at pressures less than 133 Pa, they observed the lowest resonance level to produce the most intense ionization signal of xenon's MPI spectrum. The ORNL group has obtained similar results with krypton and argon.

Why is intense ionization of rare gases observed at low pressures, whereas none is seen at high pressures? Ray Garrett, head of HASRD's Chemical Physics Section, and Marvin Payne have proposed a theory: When the laser photons are tightly focused in xenon, the resulting excited xenon atoms are close and begin to "feel" each other. As the pressure increases, the average separation between the excited atoms is so small that they form a collective state and radiate collectively on a time scale much shorter than the radiation lifetime of a single, excited xenon atom. Because the light emitted by the collective state has an energy of exactly three times that of the exciting laser photon, it is called third-harmonic generation light. The key point is that the ionization disappears because the third-harmonic light depletes the excited states that would be ionized by the laser.

Payne and Garrett developed a theory of harmonic light generation together with the collective state phenomenon. Fortunately, in the case of xenon and other rare gases, their theory and the experimental results agree. Also, this vacuum ultraviolet light is bright, pulsed, tunable, and very monochromatic and can be used for a multitude of purposes, some of which are being studied in HASRD. One important application is the detection of hydrogen atoms in tokamak plasmas.

CHEMICAL TECHNOLOGY,

March 24 and 25

Partitioning and Transmutation of Actinides from Radioactive Wastes

Recent interest in waste partitioning, which is the separation and recovery of alpha-emitting actinides from fuel cycle wastes, and in the transmutation of these actinides to less harmful isotopes by neutron irradiation has led to a feasibility study reported by Allen Croff. Partitioning-transmutation (P-T) is a method of treating wastes before subsequent disposal.

The candidate nuclides are primarily the transuranic actinides, with special interest given Np, Pu, Am, and Cm. Of secondary interest are the long-lived fission products ^{129}I and ^{99}Tc. These nuclides would be found in a wide variety of wastes produced by spent-fuel reprocessing and uranium/plutonium fuel fabrication plants.

The proposed actinide separation and recovery method for the high-level wastes involves additional Purex extraction during its generation followed by bidentate extraction of actinides and trivalent lanthanides and separation of the trivalent actinides by cation exchange chromatography. Recovery of actinides from salt wastes is based on alcohol extraction followed by tributyl phosphate (TBP) and bidentate extraction steps. Solid wastes are prepared for actinide recovery by leaching with nitric acid containing either hydrofluoric acid or ceric nitrate.

Transmutation of actinides is entirely feasible in thermal reactors and liquid-metal fast breeder reactors (LMFBRs) in a variety of recycle modes. Recent studies have shown that fusion reactors are not as effective for actinide transmutation as was originally thought. Actinide transmutation rates in thermal reactors proved to be about 6.4% per full-power year of reactor operation, or about 3% per calendar year, and about 50% higher in an advanced-oxide LMFBR. The low transmutation rate for ^{129}I (about 3% per full-power year) and other problems make its transmutation unlikely; however, the transmutation rate for ^{99}Tc, about 11% per full-power year, makes its transmutation probably feasible.

Cost studies and risk analyses have been performed to determine P-T viability. Incremental costs of P-T were a little under 1.3 mills/kWh(e) [$9.2 $\times$ 10^6 per GW(e)-year], equivalent to 2.9% of the average cost of U.S. residential electricity in 1978, or $1.50 for each person. The risk analyses showed that P-T increased the relative short-term radiological risk by a factor of 5 and the dominant nonradiological risks by a factor of ~ 3. The expected long-term health effects, integrated over a million years of repository life, showed a person-rem equivalent of 25,500 compared with the reference figure of 25,800. Thus the benefit of P-T is a reduction of about 300 person-rems per GW(e)-year. The study showed this benefit to be equivalent to about 0.001% of natural background radiation. Moreover, the impacts of the actinides are virtually eclipsed by the long-lived ^{99}Tc and ^{129}I.

Therefore, the costs and short-term risks of P-T, balanced against the long-term risk reduction, result in a net increase in risk (because the short-term increase is greater than the long-term reduction) as well as substantial short-term costs. Because P-T increases the neutron activity of fuels, the actinides would require more stringent protection in the form of thicker shielding, remote handling, and esoteric shipping cask design.

The study group concluded that actinide partitioning appears to be feasible with current technology, but the small benefits make its practice or further investigation inadvisable. Partitioning of ^{129}I is probably feasible, but transmutation is most likely not. The feasibility of ^{99}Tc partitioning is unknown, but its transmutation appears to be feasible. If conservative repository risk analyses continue to be used, there may be incentives for reducing the levels of these latter two nuclides.

As he makes clear in the accompanying reminiscence, physicist Bill Good came to the Laboratory in the very early days. In 1974 he left the Physics Division to join the Health Physics Division, from which he retired in 1978. He frequently consults for his former colleagues, however. He is shown here with fellow retiree Art Snell (standing) at the high-voltage terminal of the now defunct 3-MV Van de Graaff accelerator, which is stripped of its protective shell. On the left is the radio-frequency ion source developed for it by Charlie Moak. During its operation, the entire terminal was held at up to three million volts positive potential with respect to ground. The pioneer accelerator was decommissioned in the summer of 1979.

Rememberances of an Accelerator Past

By WILFRED M. GOOD

In July 1979 a short ceremony formally ended the life of the 3-MV Van de Graaff accelerator as an ORNL research tool. This instrument, often referred to as the 3 MV, in its origin and during its maturity saw the Laboratory develop from beginnings filled with uncertainty to the position of respectability that it holds today.

My connection with the 3 MV began in uncertain early days, and my recollections begin around 1948, when I had been at the Laboratory for about two years. At that time the predominant opinion of the Atomic Energy Advisory Committee was that ORNL's sister laboratories at Los Alamos, Argonne, and Brookhaven were adequate to carry on the nation's program to develop nuclear energy for peacetime use; if ORNL were to continue its participation, it would have to continue without new facilities. Nevertheless, there prevailed at ORNL a spirit of enthusiasm over the prospects for peaceful applications of nuclear energy and a strong conviction that the Laboratory had contributions to make.

Alvin Weinberg had recently become the new director of research, and Art Snell had been appointed as head of the Physics Division.

Such was the climate when Weinberg and Snell asked me to take the responsibility of starting a Van de Graaff accelerator program. The objective was clear: neutrons were the key to the new frontier of applied nuclear energy; to fully exploit neutrons, their behavior must be thoroughly understood; and the Van de Graaff was the only known source of

Jack Gibbons and Dick Macklin in August, 1964, prepare for neutron capture experiments, using the 3 MV. Their cross section measurements were to make cosmic theory history.

neutrons of precisely determined energies above 1 keV.

My background did not include experience with accelerators, and I considered myself a weak candidate for the responsibility that I was asked to take. However, I accepted it. My motivation was first the desire to contribute, if possible, to the realization of nuclear energy as the ultimate energy source, beginning with nuclear fission, and second, the desire to broaden my horizons.

The undertaking called, of course, for some sort of group endeavor; the first step in this direction came about when Charlie Moak agreed to join me in the effort. Thus the Physics Division acquired a Van de Graaff group—a group of two persons with no applicable experience, no funding, and no equipment.

At the zenith of its career, the 3 MV to which this article is dedicated became a sophisticated instrument for neutron research; but in the beginning it was a rather simple 2.5-MV electron accelerator. The evolution from a 2.5-MV device to the 3-MV instrument took place during a period of time that extended roughly from 1950 to 1964. The course of that evolution was strongly influenced by the initial condition that we necessarily had to "make do" with what we had on hand. The resources at hand included an assortment of materials from the discontinued Y-12 operations, but a more significant item was a General Electric betatron that the Laboratory had purchased earlier. However, this instrument was obsolete almost before it was delivered, and Snell courageously recommended that it be abandoned in favor of one that produced positive ions.

Knowledge came from Don Richardson that the Chemistry Division had another resource in the form of a 2.5-MV electron accelerator. The eventual acquisition of this machine for protons was somewhat coincidental in that Dick Lamphere, an engineer in the

Instrumentation and Controls Division, had worked with Professor Trump at the Massachusetts Institute of Technology to develop the prototype of the machine. Thus, we proposed a joint program between the Chemistry and the Physics divisions to convert the electron accelerator to a proton (positive ion) accelerator compatible with electrons, provided Lamphere could be induced to engineer the conversion. Clancy Hochanadel and John Ghormley of the Chemistry Division, for whom the 2.5-MV electron machine was principally procured, agreed to the plan, and Lamphere joined us in our efforts.

Space does not permit a detailed chronicle of the immediately ensuing developments and their anecdotes. Briefly, Lamphere made some calculations from which he reached the hopeful conclusion that the 2.5-MV electron accelerator might be converted to 3-MeV protons—subject, however, to the disturbing condition that an ion source having ten times the efficiency of those currently in use could be devised. Lamphere brought with him an electrical engineer, Rutledge King, and several technicians, thus providing the Physics Division with considerable expertise and a consequent saving of time.

The development of the ion source was undertaken by Charlie Moak, who, in due time, produced a new type with essentially the required characteristics. By good fortune, almost simultaneously Lamphere's accelerating tube that he had designed for protons was completed. It was a great day when the 2.5-MV electron machine delivered a 3-MeV beam of protons of record proportions—more protons, in fact, than we knew how to use. Bombarding a lithium target with the proton beam produces a stream of neutrons.

By this time changes were taking place in the Laboratory and new personnel were coming in at a steady rate. In particular, the Physics Division was acquiring personnel to support a Van de Graaff accelerator program. Two of the persons were Joe Bair, who brought with him the 5-MV Van de Graaff that he had promoted for Nuclear Energy for the Propulsion of Aircraft, then being merged with ORNL, and Joe Fowler, who was to direct the new and larger Van de Graaff laboratory. The time had thus come to dedicate the 3 MV fully to neutron investigation. Although it was already partially devoted to neutron study, the soundest approach to full-time dedication seemed to be an adaptation for applying to fast neutrons the time-of-flight principles that had proved so successful for slow neutrons.

The plan to utilize time-of-flight principles for fast neutrons imposed challenging new problems. To begin with, there was the problem of using the full beam potential of the new source without sacrifice. It already seemed clear that essentially the only approach was the novel one of producing the required 10-ns proton bursts inside the terminal (at 3 MV potential) prior to acceleration rather than using the prevailing practice of postacceleration burst production on the emerging beam. The scheme was successfully accomplished in due time by Moak and Rutledge King, although mention should be made of participation by Cleland Johnson, especially for his observation that the "beam-chopping" employed for burst production introduced an energy spread in the pulsed beam.

Data acquisition was a separate matter that brought with it at once the new problem of measuring time in nanoseconds. This problem was solved by John Neiler, who was relatively new in the Physics Division. Time-of-flight data proved to be voluminous, and other new division members, Phil Miller and later John Biggerstaff, adapted the data to computer processing so that the mass of information could be efficiently managed. It was not long after neutron measurement became more or less routine that the need to supplement two-parameter data with three-parameter data became apparent. Neiler and Biggerstaff, along with certain foreign participants, provided an on-line solution, which was novel at the time.

However, neutron intensity remained a problem. Thus, when P. R. Bell brought with him from his visit to the Soviet Union word about a radically different ion source invented by Von Ardenne and called the duoplasmatron, he promoted a renewed interest in ion sources. Moak, who investigated the source, found it to have singular advantages and adapted it to Van de Graaff use. To achieve the ultimate with this source consistent with the available power, King, in a separate development, provided klystron bunching at the terminal so that the inevitable energy spread associated with burst production could be profitably used to further increase the intensity of the pulses at the target. Thus for a short time, the 3 MV reached the pinnacle as a source for neutron studies at energies above 2 keV. Other contributors to the development and operation of the 3 MV include Gene Banta for the successful targets and for general planning, John Judish for execution of details and efficient day-to-day operation of the instrument, and Jim Johnson for the ingenious and intricate spatial designs in the terminal; all were members of the Instrumentation and Controls Division.

A genuine need for further increases in neutron intensity still existed. The technology and principles of positive-ion-induced neutron pulses had been established by the 3 MV. However, the existing machine had reached its limits in regard to further development. Furthermore, a competing device, the linear (electron) accelerator (LINAC), which had undergone development elsewhere almost simultaneously with the 3 MV at ORNL, had greater versatility and flexibility than had the 3 MV. Hence, to meet its future needs for greater neutron intensity, ORNL received funds for the new LINAC. The 3 MV was slowly abandoned for neutron research in anticipation of superior results with this new instrument.

Throughout the development period of the 3 MV, opportunities to perform physics experiments were seized upon whenever circumstances permitted and modest contributions were made. In the course of the original ion source development, it was possible to study a few light charged-particle reactions, principally by virtue of the unique availability at ORNL of H^3 and He^3. Thus, it was possible (1) to establish the existence of a doubtful state in the He^5 and Li^5 nuclides, (2) to show the likely instability of the diproton to establish new energy level schemes for Be^8 and B^8, and (3) to measure the cross sections for the $He^3 + He^3 \rightarrow He^4 + 2\,p$ stellar reaction.

After the 3 MV became operational and before it was adapted for time-of-flight data, neutron reaction study had already commenced with a study of the angular distribution of fission fragments by Lamphere. Following the adaptation to time of flight, a full-time program of neutron reaction study above 2 keV neutron energy was initiated. The measurements were then made in the distinguishable areas of total cross sections, radiative capture cross sections, radiative capture gamma-ray spectroscopy, and fission. Jack Gibbons, who was already experienced in isotopic cross sections, helped Miller and Neiler institute a systematic effort to extend information on isotopic total cross sections. Dick Macklin later joined this group as it undertook the more difficult problem of radioactive capture cross sections; their measurements of isotopic capture cross sections on the 3-MV pulsed Van de Graaff made history by verifying quantitatively the theories propounded at California Institute of Technology by W. A. Fowler's group, which regarded the origins of the elements by nucleosynthesis in the centers of stars. Finally, Biggerstaff joined the group and, in association with certain foreign visitors, successfully obtained resonant capture gamma-ray spectra. This achievement was the first of its kind above 2 keV, and interesting new results were to come.

As soon as performance began to be routine, the neutron facility became available to researchers outside the Physics Division; the studies of fission by Larry Weston and Gerard DeSaussure and the studies of neutron nonelastic reactions by Francis Perey and Kirk Dickens, all of the Neutron Physics Division, deserve special mention.

In addition to its general contributions to instrumental technology and to physics, the 3-MV project made modest contributions, both directly and indirectly, to Laboratory programs. Its most notable contribution was in furthering the Laboratory effort to demonstrate ion-beam plasma heating and enter into the field of thermonuclear research and development. Pilot experiments under the direction of Bell and John Luce were expedited by using the 3 MV's ion source development and test equipment as well as prototype ion sources. The results provided the basis for ORNL's exhibition at the first Geneva conference. An indirect contribution to the Laboratory was the 3 MV's influence on acquiring a modern computer at ORNL to replace the obsolete Oak Ridge Automatic Computer and Logical Engine (ORACLE). The basis for this computer was the requirement for essentially on-line data processing for effective and efficient time-of-flight data acquisition.

When neutron study with the 3 MV ceased by virtue of a newer and more intense neutron source, the 3 MV continued to function in other capacities—but that is another chapter for another author. In retrospect, the 3 MV was a gamble. From the viewpoint of a physicist, the gamble was somewhat disappointing in that it yielded no surprising new information and no new insights as crowning achievements for the effort. Some measurements that were made utilized properties that were unique to the 3 MV, and these may never be repeated. The refinements of detail that the instrument's higher resolution gave to existing information served to further confirm the essential correctness of the basic understanding of neutron interactions.

lab anecdote

Ioi Lasterren Wake-Potentziala Egoera Solidoan

A former guest scientist of the Laboratory and an ORNL physicist recently published the first research physics article ever printed in Basque, a language that has survived attempts to suppress it.

The former guest scientist is Pedro Echenique, an enthusiastic Basque and collaborator of Rufus Ritchie, a well-known theorist in ORNL's Health and Safety Research Division and one of several scientists recently designated Corporate Research Fellow by the Nuclear Division of Union Carbide Corporation. Echenique first met Ritchie in 1975 when the ORNL physicist was a visiting professor at the Cavendish Laboratory, the physics department of Cambridge University in England, where Echenique earned his Ph.D.

In 1976 Ritchie invited Echenique to ORNL as a postdoctoral fellow to conduct theoretical studies related to surface physics and the penetration of fast particles through condensed matter. Shortly after his arrival, Echenique learned of an interview with a high Spanish official by the French magazine *Paris-Match,* in which the Spaniard stated that the Basque language lacked the capability of meeting the needs of scientific societies. Said the official: "One cannot talk about nuclear physics in Basque."

The interview gave Echenique the idea of writing a scientific research paper in Basque. Ritchie approved the idea and offered encouragement, so Echenique began writing the paper while working at the University of Barcelona in Spain.

Entitled "Wake Potential of Swift Ions in Solids," this paper, coauthored by Echenique and Ritchie, was recently published in the journal *ELHUYAR,* the only publication in Basque that deals with the physical sciences. The article concerns the wake theory, which was developed by Jake Neufeld and Ritchie in 1955. According to this theory, a swift positive ion passing through the "sea" of electrons in a metal crystal or liquid attracts electrons and creates a "wake" of electron density that oscillates as it trails behind the ion. Various effects may be caused by the electric field created by the negatively charged wake on the positive ion.

Since 1973 a number of experiments have helped to substantiate and resolve the wake theory, which has been worked out further by Ritchie, Echenique, and Werner Brandt of New York University (NYU). These experiments are being performed at ORNL, NYU, Argonne National Laboratory, Weizmann Institute in Israel, and the Institute of Nuclear Physics in Lyon, France. Some experiments have shed light on the structure of molecular ions penetrating solids. A recent ORNL experiment that helped substantiate the wake theory resulted in the discovery of the "resonant coherent excitation" effect.

Echenique, who left ORNL in 1979 for the University of California at Berkeley, is excited by the publication of the physics article in Basque because of his interest in upgrading education and encouraging academic scholarship and research among the Basques. His hopes for the academic advancement of the Basques are encouraged by the presence at ORNL of Jacinto Iturbe, a young Basque scientist who is working for Sam Hurst of the Health and Safety Research Division.

The Basques include about three million people who live around the Bay of Biscay on both sides of the

Rufus Ritchie (left) discusses the wake theory with Pedro Echenique.

Occidental Pyrenees on the border between France and Spain. Recently, the Basques were granted some autonomy by the Spanish government. However, for many years after the Spanish Civil War, the Basque language was forbidden at schools, and there was no Basque radio, television, or newspapers. "It is not surprising that very little physics has been written in Basque," says Echenique. "What is really surprising is that Basque is alive at all. But it is alive, and thanks to the work of many people, a resurrection of Basque has been achieved."

With financing from private sources, the Basque schools (*ikastolas*) have begun teaching in Basque at the elementary stage. Today, some university professors are teaching physics and chemistry in Basque at the University of Bilbao. Basque is a pre-Indo-European language of western Europe, but it is not related to any Indo-European language or to the other two pre-Indo-European languages alive in Europe—Hungarian and Finnish. Surrounded by Romance languages, it is an island tongue. It is a linguistic treasure for language experts all over the world who are fascinated by its grammatical structure and other peculiarities.

When Echenique left ORNL last year, he stated how much he appreciated the hospitality of Ritchie's group and how pleased he was to have collaborated with Ritchie in writing the first physics research paper to be published in Basque. Or, as he put it in Basque, *"Fisika ikerketaz euskaraz idatzi den lehen lanetan."*—C.K.

Research Impacts of Environmental Assessments

By CAROLYN KRAUSE

One of the first environmental reports drafted by a utility in compliance with the National Environmental Policy Act (NEPA) of 1970 is 20 pages long. A decade later, a typical environmental impact statement submitted to the Nuclear Regulatory Commission (NRC) consists of thousands of pages filling nearly 20 volumes, a stack of which may equal the height of a ten-year-old child.

The proliferation of paperwork spawned by NEPA really began after the landmark Calvert Cliffs decision of July 23, 1971, when the Atomic Energy Commission (AEC) was ordered to issue detailed environmental impact statements for nuclear power plants in the planning stages or in operation.

According to Tom Row, head of the Environmental Impact Section of ORNL's Energy Division, the

Tom Row (left), Bob Craig, and Bud Zittel of the Energy Division pore over an ORNL report. At top right is a three-volume environmental report to which ORNL made significant contributions. Row heads ORNL's Environmental Impact Section, which prepares environmental assessments and impact statements on federally funded projects in nuclear energy, coal conversion, fossil fuel combustion, solar energy, geothermal energy, hydroelectric power, and fusion.

early environmental reports were slim because of the vagueness of the law and the paucity of research related to water quality and other environmental impacts of power plant operation. Since then, court decisions, changes in government agency posture, and impact statement work performed by ORNL, Argonne National Laboratory, and Pacific Northwest Laboratory have firmed up the interpretation of NEPA. The questions raised by NEPA have also sparked a considerable amount of field research and computer modeling studies, the results of which have contributed to the expansion of environmental impact statements and assessments. Says Row: "The impact of this program on research at ORNL has been exceptional. It has broadened the scope of research activities into many new energy areas."

Some of the environmental research and modeling work was done at ORNL, which has a wide range of disciplines and experience that could be applied to questions that ORNL writers of impact statements were trying to tackle. One well-known example of ORNL research pertinent to impact assessment is the work that led to the development of the temperature-sensitive ultrasonic fish tag to determine the effects on fish of heat discharges from power plants using ambient waters for cooling.

Early large impact statements devoted hundreds of pages to the discussion of fish protection, with only a few pages dealing with reducing unfavorable impacts on people. These priorities have changed because of NEPA interpretations calling for consideration of power plant impacts on the community as well as the environment. Thus, at ORNL the Social Impacts Assessment Group of the Energy Division was formed to examine the socioeconomic impacts of reactors on area residents during construction and during and after operation. Most of today's impact statements include monitoring and mitigation plans to help communities prepare for adverse impacts that may precede beneficial effects. Research on the construction and operational phases of these large energy facilities has provided excellent guidance for the development of these plans.

The Laboratory has considered a number of questions raised by NEPA assessments of potential impacts of nuclear power plants in an effort to find a balance between costs and benefits that the American society considers acceptable. Some examples are: How much radioactive material is released to the environment by discharges of gases during normal operation of nuclear plants? What are the impacts on aquatic organisms passing through power plant cooling systems or exposed to heated water discharged by the nuclear facility? What are the environmental effects of cooling towers? How can cooling water intake and discharge structures be constructed and operated to

"... and in this room we keep the 5000-page statement on the impact on pulpwood forests of the environmental impact statement efforts."

A temperature-sensing ultrasonic fish tag has been inserted into this striped bass from Cherokee Reservoir.

Fish Temperature Telemetry

Fish don't wander about just anywhere in the lakes, rivers, and estuaries that man wishes to use for energy developments such as power plant cooling. Siting facilities for minimal damage to fishery resources requires a knowledge of where important fish populations are located, when they are found at particular spots in daily and seasonal cycles, and what environmental cues lead them to certain habitats. Traditional methods of surveying each proposed site by collecting large numbers of fish with nets or other devices are both expensive and destructive of the resource we want to protect. Better methods became needed as the number of projected facilities rose dramatically about ten years ago.

Early fishery studies of power plant impacts at Hanford on the Columbia River and at the Connecticut Yankee Atomic Plant on the Connecticut River demonstrated the values of ultrasonic transmitters for following fish movements past thermal discharges. The major drawback to these early studies was the difficulty of correlating movements with the environmental factors being changed, mainly temperature. It was also difficult to use these site-specific fish behavior data to predict responses at new sites, which is the major task of environmental impact assessments. The need to accurately predict responses of fish species to temperature changes was apparent. One solution seemed to be with an electronic fish tag that would transmit temperature data as the fish responded to environmental changes.

A temperature-sensing ultrasonic fish tag was thus developed at ORNL by Jim Rochelle of the Instrumentation and Controls Division. Since 1971, Chuck Coutant and his Environmental Sciences Division team have been using this fish tag in field research to determine temperature preference data. Preferential temperatures for adult largemouth bass (27°C), smallmouth bass (25°C), and striped bass (20°C) have been measured in local waters. Several companies now sell temperature-gathering telemetry equipment based on the ORNL device. The Tennessee Valley Authority and many other utilities or their consultants employ temperature telemetry as a standard procedure in field monitoring.

Fish telemetry work at ORNL stimulated recognition of the importance of temperature selection for determining power plant impacts on fish. Thermal preferences of a species were found to correspond with its optimum temperature for growth, which is an important determinant of water temperature standards. Avoidance of temperatures above those preferred was recognized as a major mechanism for preventing environmental damages so long as cooler temperatures were available nearby. Routes and mechanisms of avoidance thus became key points for impact evaluations. The Laboratory has tabulated thermal preferences of nearly 100 fish species from a variety of literature sources for use in defining environmental requirements in impact assessments. These data are a standard reference tool of impact assessments today.

Aboard a U.S. Army Corps of Engineers boat, Tom Row takes part in a site visit to several Hudson River power facilities, including the Indian Point Nuclear Power Plant seen in the background.

minimize their impact on fish and other aquatic life? What impacts can result from discharge of cooling system treatment chemicals such as chlorine to a receiving body of water?

We have also studied problems related to impacts of nonnuclear energy sources, such as the effects of geothermal energy development on an American Indian community, the environmental effects of exploiting small dams for power generation, and electricity demand forecasting.

Impacts of Nuclear Energy Sources

Radioactive Emissions. Shortly after the Calvert Cliffs decision, it became apparent that the required analysis of environmental impacts of nuclear power plants on a mass basis could be greatly expedited by standardizing some of the analytical procedures. The Laboratory's Environmental Reports Project, formed in late 1971 under Ed Struxness to aid the AEC in preparing dozens of impact statements for reactors, assumed the assignment to develop a standard method for computing the release of radioactive material during normal operation for all proposed nuclear power plants. This task was carried out by Frank Binford and Tom Hamrick of the Operations Division, assisted by George Parker of the Reactor Chemistry Division, Michael Ball of the Chemical Technology Division (now with NRC), and Tom Row (then with the Reactor Division).

The result was a design for generating "source terms" for use in calculating the nuclear plant's environmental impact due to gaseous radioactive effluents. Source terms are lists of the quantities of isotopes expected from plant operation and the fraction that would actually be released. The procedures are still in use, with some modification.

Binford and Hamrick also developed a standard procedure taking atmospheric dispersion into account to calculate the average dose rates to the public which result from radioactive gaseous emissions during normal operation.

Unified Transport Approach. The Laboratory is reputed to have all the necessary capabilities for preparing scientifically sound and publicly defensible environmental impact statements. This reputation is partly a result of our development and use of mathematical models for the assessment of power plant impact on aquatic environments. The various transport models and their computer codes were developed in 1971-73 in a joint program between ORNL and The University of Tennessee under the direction of Bill Fulkerson, now director of the Energy Division, and consultant Arsev H. Araslan.

For example, several models have been used for predicting the impact of multiple power plant operations on the aquatic life of the Hudson River. Impacts are calculated by simulating scenarios of accidental radionuclide releases, thermal discharges, formation of potentially hazardous chloramines caused by chlorine discharges, and entrainment and impingement of fish by power plant cooling systems. These models save time and money in their site-specific analyses of power plant impact and are in widespread use.

Fish Population Modeling. The Fish Population Modeling Project started in 1971 when Phil Goodyear, formerly of the Environmental Sciences Division and now with the Fish and Wildlife Service of the Department of the Interior, had to grapple with the question of entrainment mortality, particularly of striped bass, at the Indian Point Nuclear Power Plant on the Hudson River. Entrainment mortality refers to the killing of small organisms such as fish eggs, larvae, and fry that are drawn through a power plant in its cooling water. There was also concern about fish losses due to

Pat Parr records data while Fred Taylor prepares a lysimeter to detect possible drift chemicals from the Paducah Gaseous Diffusion Plant cooling towers.

impingement—capture of larger fish on intake screens.

The Laboratory initiated modeling efforts directed both at answering questions raised at Indian Point and at developing tools that could be applied in other situations where environmental assessments were required. The federal government is still using these models in adjudicatory hearings to argue that newer power plants on the Hudson River should install cooling towers because they withdraw substantially less than 10% as much water as once-through cooling systems and therefore have a much less severe impact on fish.

The scope of this research—carried out in the Environmental Sciences Division by Larry Barnthouse, Sig Christensen, Bernadette Kirk, Webb Van Winkle, and Doug Vaughan—has been expanded to include other projects related to power plant impacts on the aquatic environment.

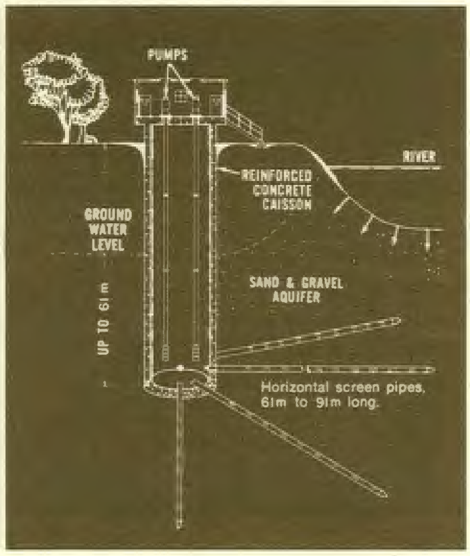
Cooling Tower Drift. In implementing NEPA, the Atomic Safety and Licensing Board (ASLB) in 1973 ordered the installation of a cooling tower at the Indian Point Nuclear Power Plant. The cooling tower was viewed as a means of meeting thermal discharge requirements and reducing fish losses due to entrainment and impingement. However, because drift from cooling towers deposits toxic salts and treatment chemicals on land, the ASLB decision shifted the potential for adverse environmental impacts from the aquatic to the terrestrial area.

To understand these impacts, Fred Taylor and Pat Parr of the Environmental Sciences Division have conducted studies since 1973 at the Department of Energy's (DOE's) uranium enrichment facilities. Because hexavalent chromium is a constituent of a corrosion inhibitor widely used in cooling towers, Taylor became interested in examining the extent to which this toxic chemical and potential carcinogen entered and persisted in the environment. Studying drift at an Oak Ridge Gaseous Diffusion Plant cooling tower, he found that almost 75% fell within 1 km downwind within DOE properties and that hexavalent chromium inhibits growth of tobacco plants.

Taylor and Par are also looking at the transfer of drift chemicals along food chains and studying their movement in soils by moisture flow. Results of their research have aided in improving environmental monitoring and preparing environmental assessments of cooling towers at the Portsmouth, Ohio, and Paducah, Kentucky, diffusion plants.

Other cooling tower drift studies are conducted under a program called METER—Meteorological Effects of Thermal Energy Releases. This program, headed by Aristides Patrinos of the Engineering Technology Division, studies the extent to which heat and moisture discharged into the atmosphere by cooling towers at energy centers may cause inadvertent weather effects, such as excessive rain and fog.

Fish Protection Devices. To reduce entrainment and impingement mortality caused by once-through cooling systems, engineers and biologists are designing fish protection devices for intake structures. Their incentive is Section 316(b) of the Federal Water Pollution Control Act, which requires the use of the



Schematic of a radial well, an exclusion device designed for the cooling system of a power plant.

best available technology in the design of intake structures. Under the leadership of Johnnie Cannon of the Energy Division, Kim Campbell and Don Lee of the Energy Division and Glen Cada and Adam Szluha of the Environmental Sciences Division examined the engineering feasibility, biological effectiveness, and costs of available fish protection devices. The report on their findings was used in the testimony in the Hudson River power case and is expected to be helpful to the utility industry, regulators, and writers of impact statements.

Cannon and his team looked at devices such as the fish-bucket-type traveling screen, which catches fish in a compact bucket beneath each screen panel and transports them to a sluice for return to the source water; the cylindrical wedge-wire screen and radial well intake, exclusion devices conceptually designed with intake velocities so low that few fish are drawn in; and the louvered and angled screen diversion systems that guide fish past intake structures. They concluded that alternative devices are available which could reduce impingement and, to a lesser extent, entrainment mortality but that the extent of reduction achievable is site specific.

Power Plant Chlorination. Chlorine is routinely used in power plant cooling systems to control fouling organisms like mussels and bacterial slimes, which can reduce the heat exchange across the condensers and thus decrease the efficiency of electricity generation. In the early 1970s, NEPA requirements called for a more comprehensive look at the environmental impacts of power plant chlorination. At that time, fish kills had been linked to excessive releases of chlorinated effluent to waterways and compounds formed by the reaction of chlorine with organic chemicals in water were considered to be potentially toxic and carcinogenic.

Several ORNL research projects have attempted to resolve a question debated by regulators, utilities, environmentalists, and writers of impact statements: What is the minimum level of chlorine required to prevent fouling and to ensure efficient operation of condenser cooling systems without inflicting unnecessary insults upon the environment and public health? John Trabalka, Jack Mattice, and S. C. Tsai of the Environmental Sciences Division have studied the toxic effects on carp embryos and water fleas of 4 trihalomethanes and 17 chlorinated organic compounds identified as constituents of secondary sewage by Bob Jolley of the Chemical Technology Division. They found that the concentration of these compounds that kills 50% of the test organisms is about 1000 times as high as the measured average concentrations of chlorine released from power plants, suggesting that these compounds in cooling water are not an environmental hazard. Many other products, however, have not yet been identified.

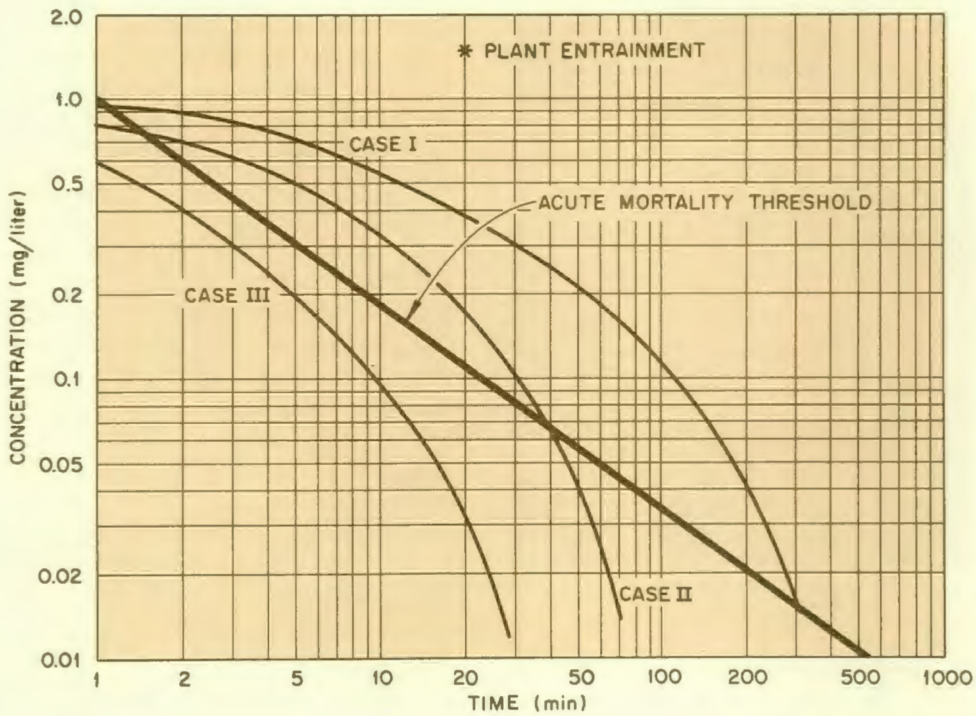
Mattice and Bud Zittel of the Energy Division have developed a model for predicting the toxicity of residual chlorine compounds. This model takes into account site-specific dilution factors and allows higher limits for chlorine discharges (and hence higher chlorination levels) in cases where dilution is extremely rapid. Used for environmental assessments and recently adopted by Environmental Protection Agency Region V for setting chlorine discharge limits, this model provides input for decisions on plant design and operational specifications and on the possible need to consider the use of alternative biocides. Several environmental scientists at ORNL are examining aspects of this model empirically.

Milt Lietzke of the Chemistry Division has developed a chemical kinetic model that traces the fate of chlorine when it enters cooling water under various conditions. The model traces reactions of chlorine with nitrogen compounds to produce toxic chloramines and also reactions of chlorine with organic compounds. The model has been tested by using data from several power plants.

Impacts of Nonnuclear Energy Sources

Geothermal Energy and the Indians. Geothermal energy existing in geyser and hot spring areas may be tapped by drilling wells into the reservoirs of hot water and steam contained by rocks near a heat source within the earth. The steam or hot water that rises to the surface can be used to power turbines that generate

The effect of power plant chlorination on aquatic organisms depends on the concentration of chlorine in the cooling water and the time of exposure of organisms. Cases I-III represent concentration-time regimes for organisms entrained in the plume of a hypothetical plant under increasing rates of discharge dilution. Organisms passing through the plant in all cases or entrained after discharge in Cases I and II would be expected to suffer some mortality, because doses exceed the acute mortality threshold. Case III represents a dilution rate that would prevent discharge impacts harmful to organisms entrained in the discharge plume.



electricity and then be injected back underground to offset potential subsidence or to be reheated for possible reuse. Although a regionally significant source of energy for direct heat and electrical generation, geothermal technology may have adverse environmental impacts, depending on the site (e.g., release of noxious hydrogen sulfide or subsidence of the surface caused by fluid withdrawal).

In a recent environmental assessment for a California geothermal exploration project, ORNL had to struggle with a cultural issue sparked by the question of what impact the development of the geothermal resource would have on shallow groundwater aquifers and surface-water systems. The environmental assessment examined the impact of a flow-testing operation needed to evaluate the energy potential of the Coso Known Geothermal Resource Area located 290 km (180 miles) northeast of Los Angeles. The problem is that the exploration well site is near the Coso Hot Springs Resort in an area of religious significance to the Owens Valley Paiute-Shoshone Indian tribe. These native Americans fear that the spirits present at the old resort would cease to exist if the hot springs and mud pots were to dry up—a possible adverse consequence of geothermal exploration and development.

Mary Moran, a geologist with the Energy Division at the time and now with the Environmental Sciences Division, has examined the potential environmental impacts to the spring system of geothermal testing and energy production. She found that the well flow test would not withdraw enough geothermal fluid to adversely affect the flow at the hot springs. This hot fluid from deep within the earth rises along the Coso Fault, mixes with more shallow groundwater, and then discharges at the surface at the resort.

However, Moran also concluded that fluids withdrawn during more extensive reservoir development and energy production could draw down the reservoir enough to deplete the geothermal component of the spring flow if the total amount of fluids were not reinjected. "At times of the year when the shallow groundwater table drops, the springs and mud pots could dry up," she recently told representatives of the California Energy Commission, DOE, the United States Navy, and the Council of Native Americans. The project has not been implemented yet but is still under consideration.

Another cultural issue involving geothermal energy and the Indians has arisen. Moran recently wrote the geology and groundwater hydrology sections of the final environmental impact statement (FEIS) released in January 1980 for the DOE Geothermal Demonstration Program 50-MW power plant at the Baca location in north-central New Mexico. One of the culturally significant potential impacts detailed in the FEIS is what effect (if any) geothermal development will have on nearby springs and the Jemez River, a tributary of the Rio Grande. Pueblos in the area not only consider all springs sacred but also use the Jemez River for various religious practices as well as for irrigation.

Water rights and Indian religion make this geothermal drill rig at Baca, New Mexico, a center of environmental interest.

Vapor plumes and pipes dominate this view of the 100-MW geothermal power plant at Geysers, California, north of San Francisco. About 80% of the geothermal steam escapes to the atmosphere rather than being returned to the ground.

The FEIS concludes that portions of the flow of some springs and the Jemez River consist of geothermal fluid outflow. Development of the geothermal reservoir could thus deplete the discharge and impact the Pueblo culture. The Indians have publicly expressed their concerns; court action may result.

Small Hydroelectric Plant Technology. Fifty years ago a third of the electricity in the United States came from hydroelectric dams, many of which have been destroyed or abandoned in the recent era of cheap oil. Now that oil is becoming more expensive and harder to get, interest has been revived in water power. By some estimates, there are many small dams, some with turbines, that have a potential total generating capacity equivalent to that of many nuclear power plants. There is considerable enthusiasm now for retrofitting existing dams to provide electricity for local communities, industries, and the power grid. Hence, in 1977, DOE initiated the Small Hydroelectric Power Development Program to encourage and accelerate the redevelopment of existing dams with capacities of 15 MW or less for hydroelectric generation. Because dams have the potential for adversely affecting aquatic and terrestrial ecosystems and land and water use, DOE requested that ORNL prepare an environmental assessment of the program.

In August 1978, Harry Arnold and Kim Campbell of the Energy Division and Dick Roop and Glen Suter of the Environmental Sciences Division prepared a draft environmental assessment of the DOE hydroelectric program. Then DOE asked the Environmental Sciences Division to prepare an Environmental Subprogram Plan that would analyze the potential constraints and benefits to the environment of developing technology for small hydroelectric plants.

In October 1978, Steve Hildebrand and Ralph Turner prepared the Environmental Subprogram Plan and ORNL was selected as the lead organization to implement the research. During 1979, Jim Loar, Lynn Dye, Hildebrand, and Turner prepared a report analyzing the environmental constraints of dredging that may be required at small hydroelectric dam sites. Under a subcontract held by The University of Washington, Hildebrand prepared a report addressing design considerations for facilities that may be required to pass fish around dams. Hildebrand, Turner, and Adam Szluha initiated an analysis of the effects of water level fluctuation at small hydroelectric dam sites.

Electricity Demand Modeling. Writers of environmental impact statements for power plants must

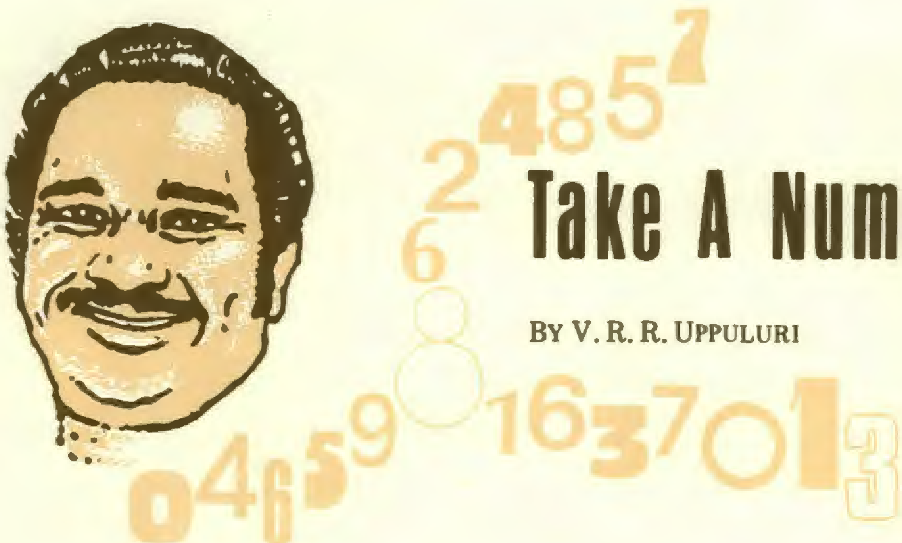
This 80-year-old Boston Falls Dam on the Winooski River in western Vermont was once a hydroelectric facility. Green Mountain Power Corporation proposes to reactivate the 50-ft-high dam to produce up to 6500 kW for 6 h/d.

show that there is a need for additional power-generating capacity to justify the construction and operation of each power plant by a specified time. Forecasting electricity demand has not been easy in the past decade because power costs rose dramatically instead of steadily declining and the growth of electricity consumption dropped to 3%, down from 7 to 8% annual growth. To improve the accuracy of energy demand forecasts, economists in ORNL's Energy Division have developed a computer model that takes into account the many factors that influence electricity demand by classes of electricity consumers. These factors include population growth, household sizes, personal income, prices of electricity and substitute fuels, heating and cooling degree-days, and industrial output. Wen S. Chern of the Energy Division and Brady D. Holcomb of the Computer Sciences Division have developed a state-level electricity demand forecasting model for NRC that has been applied to a wide variety of hypothetical cases expected under NEPA as well as to actual cases in Greene County, New York; New England; Charlestown, Rhode Island; Sundesert, California; and Erie, Ohio. Other models are being developed by Richard C. Tepel and John L. Trimble for utility service areas.

Benefits of NEPA Work. Some people have criticized ORNL's involvement in NEPA activities, saying that the work is not creative or fulfilling enough for the staff. Row disagrees with this criticism, pointing out that each impact statement requires a unique approach and that the growing amount of assessment work in the nonnuclear field offers new challenges. A recent ORNL report states that the methods, theory, and data bases used for impact analysis "are continually being developed so that the job is not really repetitive." The report compares assessment work to some fields of engineering development having codes of practice that must be followed but that leave room for innovation.

Numerous innovative research projects have been stimulated at ORNL by the need for information to resolve questions posed by NEPA assessments. And there is likely to be more research as ORNL does follow-up studies of energy projects it has assessed as a way of validating its environmental impact statements and improving future ones. ornl

Additional information on ORNL's involvement in environmental assessment is available in "ORNL and the Calvert Cliffs Decision," ORNL *Review*, Summer 1972; "The Hudson River Power Case," ORNL *Review*, Winter 1979; "Socioeconomic Impacts of Nuclear Power Plants," ORNL *Review*, Fall 1979; and "Is It Raining in Georgia?" ORNL *Review*, Summer 1978.



Take A Number.....

BY V. R. R. UPPULURI

Is There a Best Strategy?

Suppose we have a die called B, with the number 3 on each of its six faces. When die B is rolled once, the probability of getting a 3 is equal to 1. Suppose we have another die called A, with 0 on two faces and 4 on four faces. When die A is rolled once, the probability of getting a 0 is equal to 2/6 = 1/3 and the probability of getting 4 is equal to 4/6 = 2/3.

If both die A and die B are rolled once, we may say that die A beats die B because the probability of finding a 4 on the roll of die A is 2/3, and 4 beats 3. If we are playing this chance game, die A will be the winner more often in the long run; the probability that A beats B is 2/3.

Suppose we have another die called C, with 2 on four faces and 6 on two faces. Because 3 appears in every roll of die B, it is clear that die B beats die C with probability 2/3.

Suppose we have another die called D, with 1 on three faces and 5 on three faces. It can be verified that die C beats die D with probability 2/3. Further, it can also be verified that die D beats die A with probability 2/3.

This means that if someone picks up a die from the four dice A = {0,0,4,4,4,4}, B = {3,3,3,3,3,3}, C = {2,2,2,2,6,6}, and D = {1,1,1,5,5,5}, his opponent can pick up a die that beats it with probability 2/3. Thus, it seems important that one know all the strategies before he can determine the best.

Waldy Generoso, a senior scientist in the Mammalian Genetics section of the Biology Division, came to ORNL as a postdoctoral fellow in 1967 after receiving his graduate degrees at the University of the Philippines and the University of Missouri. He joined the staff the following year and has since performed extensive research in the field of mouse genetics and mutagenesis. Recently, he and his colleagues discovered an extraordinary repair mechanism that occurs in the fertilized eggs of mice impregnated with genetically damaged sperm.

Chromosome Repair in Female Mice

(based on an interview with Walderico Generoso by LaRue Foster)

A discovery by geneticists in the mammalian genetics and development group in the Biology Division has important implications for further research. Walderico Generoso and fellow researchers Katherine Cain, Maryala Krishna, and Sandra Huff knew from earlier studies that unfertilized female germ cells from mice have the ability to repair chemically induced damage to their chromosomes, the genetic material that is passed on from parent to offspring. But questions remained: Could the eggs also possibly repair damage that might exist in sperm cells used to fertilize them? If so, at what stage of embryo development would the repair take place?

The answers to these questions are of interest not only to geneticists, but also to toxicologists who study the effects of chemical mutagens—chemicals that are known to cause inheritable changes by breaking chromosomes in germ cells. One way scientists measure the extent to which a chemical damages chromosomes is by the percentage of embryo deaths among eggs that have been fertilized by sperm from males exposed to the mutagenic chemical. The chemically induced damage to the sperm does not interfere with egg fertilization but results in "dominant lethality," the death of

Generoso points to the single unsuccessful embryo in the otherwise healthy litter. The dominant lethal mutagen usually strikes within five days of uterine implantation of the fertilized egg.

the resulting embryo early in its development.

To answer these questions, Generoso and his colleagues conducted a series of so-called dominant-lethal experiments, which measure the percentage of embryo mortality in cases where chromosome damage is expected to be lethal to the fertilized egg.

First, the scientists mated female mice of four different stocks with males of a single hybrid stock which had been treated with a mutagenic chemical at doses that are expected to produce about a 50% mortality rate in embryos. Surprisingly, the actual mortality rate varied widely, ranging from a high of 81% in one female stock to a low of 9% in another. Clearly the wide variation in the survival rate of the embryos, although only one stock of treated males was used in the experiment, suggested that the repair mechanism present in an unfertilized egg could not only repair its own damage but damage to the sperm that fertilized it as well.

Generoso and his group also found that the ability of fertilized eggs to carry out repair and permit survival of the embryo varied from one stock to another (sometimes diametrically), depending on the chemical mutagen used. This finding suggests interesting possibilities: there might be more than one type of repair mechanism in the egg, and one or more repair mechanisms might be missing in some stocks.

The salient clue, to be sure, that alerted Generoso and his research team to the existence of the repair mechanism in fertilized eggs was the wide discrepancy in response by the different female stocks to the chemical insult. But the initial use of more than one female stock was not a matter of choice, but luck. At first the work was of relatively low priority, and first choice of available mouse stocks always went to high-priority projects. As Generoso says, "There weren't enough mice of any single variety

Lynn Cunningham (left) and Carol Hellwig, technicians in Generoso's laboratory, work with the impregnated mice.

available, so we had to take the leftovers from several stocks." The leftovers turned out to be the best possible choice.

A significant first step had been taken by the biologists, but it was just that, a first step. The next step was to determine at what stage of embryo development the repair takes place. Microscopic analyses of the fertilized eggs at different stages of cell division following fertilization revealed that changes were already evident by the time of the first division. Eggs from female stocks that yielded a high percentage of lethal embryos also showed a high percentage of chromosome damage at this early stage. Stocks with high rates of embryo survival showed a low percentage of damage. The researchers concluded that repair must begin very early, between the time of fertilization and the time the egg first divides, affirming the researchers' belief that the repair mechanism must have previously been present in the egg and supporting the evidence to this effect derived from earlier studies that had led them to their present work.

The discovery has important implications for toxicologists who test chemicals for mutagenic effects. The dominant-lethal test in mice is one of the methods used today to determine the extent of chromosome damage caused by a chemical in germ cells. It is not obvious whether results of previous tests could have been distorted, because the mortality rate among embryos had been affected by the female mice used in the experiments. The effectiveness of the egg repair mechanism could make the chemical appear to be less harmful than it actually is.

Greater accuracy in future dominant-lethal and other germ-cell mutation studies can now be expected because the mice for such experiments can be selected from those stocks that lack the ability to repair chromosome damage. By breeding repair-deficient female stocks with chemically treated males, the testing of suspected mutagens should become much more reliable. Generoso and his group have already started the search for such stocks for use in practical testing.

For Generoso and his co-workers, the answers to their questions have opened up more lines of inquiry. They have yet to learn the exact nature of the repair mechanism. It could be an enzyme or, more likely, a complex set of enzymes that effects the repair to damaged chromosomes. How the process works is also unknown. Currently, Generoso is conducting studies to determine the genetic nature of the repair process. So far, he has found that the ability to repair chromosome damage appears to be a dominant trait.

Another question that the scientists are considering is whether repair capability differences that exist among the egg cells from females of different stocks also exist in somatic cells, that is, those not related directly to reproduction. Cytological and biochemical studies now under way by Anton Beck and Edward Bernstine, also of the mammalian genetics and development group, may provide an answer. This research promises to yield certain basic information, not only on the important relationship between repair processes and mutagenesis, but also between these processes and teratogenesis (the production of an abnormal fetus) and carcinogenesis (the development of cancer). If the repair mechanism is found to extend to other body cells, this finding could have great significance for cancer research, leading the way to exploration of the variation in susceptibility to cancer among different individuals. Much of the information that can now be obtained by using carefully selected breeding stocks for the experiments will enable scientists to work with greater accuracy.

Generoso acknowledges the luck that his "leftover" mice brought. Furthermore, he says, "At ORNL, we are fortunate to have the opportunity to follow up on new discoveries. At many laboratories a discovery such as our initial find would simply have been noted and shelved in favor of other priorities. Here, we can pursue basic research where not every project has an immediate payoff but benefits science over the long term." ornl

awards and appointments

A number of ORNL staff members and departments won awards in the recent publications competition, sponsored by the East Tennessee chapter of the Society for Technical Communication (STC), and art competition, cosponsored by STC and Industrial Graphics International (IGI). The "Best of Show" and first- and second-place winners in the jointly held local competions were also entered in the International STC publications and art competition, where Laboratory publications took three awards. Local competition winners received their prizes at the Awards Banquet, which was held January 15 at the Hyatt Regency Hotel in Knoxville, Tennessee. Winners in the international competition received their awards at the 27th International Technical Communications Conference, which was held in Minneapolis, Minnesota, in May 1980.

The "Best of Show Award," which covers all categories, went to **John Waggoner** (Engineering Division) and the Information Division's Central Publications Office (CPO), **Donna Griffith** (editor), for *ORGDP Site Planning—A Master Plan for Site Development.* This publication also received the award of distinction (1st place) in the handbooks and manuals category.

In the annual reports category, the award of excellence (2nd place) was given to the Program Planning and Analysis (PP&A) office, the CPO, and **Donna Griffith** for the *1978-1984 ORNL Institutional Plan.*

In the bulletins and brochures category, the award of distinction went to **Bonnie Talmi, Tykey Truett,** and the CPO for the *ORNL Technical Information Center Program;* the award of distinction went to the ORNL Library System staff, the CPO, and **Donna Griffith** for *The ORNL Library System and You;* the award of excellence went to **Joe Gollehon** and **Bill Clark** for *Science and Engineering at Oak Ridge;* and the award of merit (3rd place) was won by **Ruby Miller** and **Bill Clark** for *Environmental Sciences at ORNL.*

In the compilations and bibliographies category, the award of excellence was shared by **Edward W. Hagen** and the Engineering Technology Division Publications Office (ETDPO) for *Common-Mode/Common-Cause Failure: A Review and a Bibliography* and by **Debbie Queener** and the ETDPO for *Bibliography of Microfiched Foreign Reports Distributed Under the NRC Reactor Safety Research Foreign Technical Exchange Program, 1978.*

In the handbooks and manuals category, the award of distinction was given to the CPO, **Donna Griffith,** and **John Waggoner** for *ORGDP Site Planning;* and the award of merit went to the Health and Laboratory Protection divisions, the CPO, and **Donna Griffith** for *Physical Fitness Handbook for Security Personnel.*

In the house organs category, the award of excellence was won by **Barbara Lyon** and **Carolyn Krause** for the Spring 79 issue of the ORNL *Review;* the award of merit was won by the PP&A office, the Publications and Visual Arts section, and the CPO for *ORNL Directions 1979-1984;* the Winter 79 issue of the ORNL *Review* won the award of achievement (4th place).

In the category of journals, the award of distinction went to **William B. Cottrell** and the ETDPO for Vol. 20, Nos. 2 and 4, of *Nuclear Safety;* the award of excellence was given to **Fred O'Hara, Jr.,** and the Engineering Coordination and Analysis section of the Chemical Technology Division for the *Coal Liquefaction Advanced Research Digest.*

In the category of journal articles and conference papers, the award of distinction was won by **J. E. Jobst,** the Engineering Technology Division, and **Ann Ragan** and **Jane Parrott** of the ETDPO for "The Aerial Measuring Systems Program," *Nuclear Safety,* Vol. 20, No. 2; awards of excellence were won by **H. R. Meyer, J. E. Till, E. S. Bomar, W. D. Bond, L. E. Morse, V. J. Tennery,** and **M. G. Yalcintas,** the Engineering Technology Division, and **Ann Ragan** and **Jane Parrott** of the ETDPO for "Radiological Impact of Thorium Mining and Milling," *Nuclear Safety,* Vol. 20, No. 3, and by **John McBride, Robert Moore, John Witherspoon, Jr., Ray Blanco,** and **Catherine Shappert** for "Radiological Impact of Airborne Effluents of Coal and Nuclear Plants," *Science,* Vol. 202. The latter three entries won awards of excellence, merit, and achievement respectively, at the International STC publications competition. Also in the same category in the regional contest, an award of merit was given to **S. M. Adams** and **R. B. McLean,** the Engineering Technology Division, and the ETDPO for "Unique Ecological Impacts Associated with Offshore Floating Nuclear Power Plants," *Nuclear Safety,* Vol. 20, No. 5. Awards of achievement were given to **Manfred Krause** and **Bill Nestor** for "Comparison of Experimental and Theoretical Binding and Transition Energies in the Actinide Region," a paper in the proceedings of the Symposium on Electron Spectroscopy held in Uppsala, Sweden, and to **B. Zane Egan, Charles D. Scott,** and **Martha G. Stewart** for "Let Hydrogenase Do It," *CHEMTECH,* Vol. 8.

In the category of newsletters, the award of distinction went to **LaRue Foster, Lynda Lewis,** and **Joanne Gailer** for the August 1979 special issue of *Lab News;*

LaRue Foster also won the award of merit for the February 1978 issue of *Lab News*.

In the news articles category, **Foster** also won the award of distinction for "Accident at Three Mile Island: How ORNL Responded," appearing in the Fall 79 issue of the ORNL *Review;* the award of excellence was won by **Carolyn Krause** for "Ductile Ordered Alloys: Materials for Advanced Energy Systems?" appearing in the Winter 79 issue of the *Review;* **Krause** also won the award of merit for "Enzymes, Plants, and Drugs," appearing in the Summer 79 issue of the *Review*.

In the periodic progress report category, the award of excellence went to **W. S. Lyon, Irene Brogden,** and the CPO for the *Analytical Chemistry Division Annual Progress Report, December 21, 1978.*

In the category of topical reports, an award of distinction was given to **Dick Rush, Anna Jo Shelton, J. L. Rich,** and the CPO for *Final Environmental Statement Related to Construction of Greene County Nuclear Power Plant;* the award of excellence was won by **Katherine M. Samuels, R. K. Kibbe,** and the CPO for *Proposed New Initiatives in Research, Development, and Demonstration for Light Water Reactor Safety and Technology;* the award of merit went to **Anna Hammons, John Drury,** and **Carol McGlothin** for *Investigations of Selected Environmental Pollutants: 1, 2—Dichloroethane;* and awards of achievement were given to **K. B. Franz, Cresson H. Kearny,** and **Anna Jo Shelton** for *Maintaining Nutritional Adequacy During a Prolonged Food Crisis;* to **Carol McGlothin, Maureen Hafford,** and the Information Center Complex for *Reviews of the Environmental Effects of Pollutants: V. Cyanide;* and to **L. F. Truett, Maureen Hafford,** and the Information Center Complex for *Reviews of the Environmental Effects of Pollutants: VI. Beryllium.*

In the art competition in the category of illustrations, **Larry Wyrick** and **Leon Smith** each won an award of excellence and two awards of merit; and **Bill Clark** won the award of excellence in the category of brochure design. Among the awards won in the International Association of Business Communicators' District II competition in Nashville last fall was the first place award won by **Barbara Lyon** and the ORNL *Review* in the category of one-, two-, and three-color magazines.

J. Peyton Moore was chosen to receive the 1979 International Thermal Conductivity Award given by the 1979 International Thermal Conductivity Conference for his contributions to thermal conductivity research.

Don Gardiner was elected a fellow in the American Association for the Advancement of Science (AAAS). **Dick Raridon** has been reelected to a second three-year term on the council of the AAAS, one of two AAAS council members representing the National Association of Academies of Sciences (NAAS). The NAAS is made up of delegates from the state and regional academies of science that are affiliated with AAAS, including the Tennessee Academy of Science (TAS). Raridon is a past president of both TAS and NAAS.

Martin Lubell has been elected to a six-year term on the conference board of the Cryogenics Engineering Organization; he is a member of the advisory committee of the applied superconductivity conferences and will serve on the program committee for the 1980 conference and as general chairman for the 1982 conference.

Don Jared has been elected to the executive committee of the National Science Foundation's Federal Laboratory Consortium for Technical Transfer.

The winner in both local and regional competitions in the "1979 Gateway to Energy Conservation Awards Program," sponsored by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers was an exhibit showing special modifications to the heating and cooling systems for the two east corridors of 4500N. Receiving the prize was **Dick Peden,** field engineer for the project.

Stanley I. Auerbach has been appointed to a three-year term on the Commission of Natural Resources of the National Research Council (NRC). **David Reichle** has consented to serve on the NRC's Board of Agriculture and Renewable Resources as a member of its Committee on Alternative Programs for Belt-Wide Cotton Insect Management. **John Witherspoon, Jr.,** has accepted appointments to the Committee on Federal Research on Biological and Health Effects of Ionizing Radiation in the Division of Medical Sciences of NRC's Assembly of Life Sciences. **Witherspoon** has also been asked to serve on Task Group 2 of Scientific Committee 64 of the National Council on Radiation Protection and Measurements. His group will be charged with identification and evaluation of environmental models for estimate of dose from discharge to surface waters. Serving on Task Group 3, which is responsible for identification and evaluation of environmental models for estimate of dose from discharge to atmosphere, is **Owen Hoffman.**

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