Oak Ridge National Laboratory

review

Fall 1979

4-Year Index

THE COVER: ORNL's ability to assist in a crisis was demonstrated last spring following the reactor accident at Three Mile Island. How various ORNL teams became involved in assessing the hazards and damage is recorded in the narrative account on page 1. (NRC photo by EG&G Las Vegas.)

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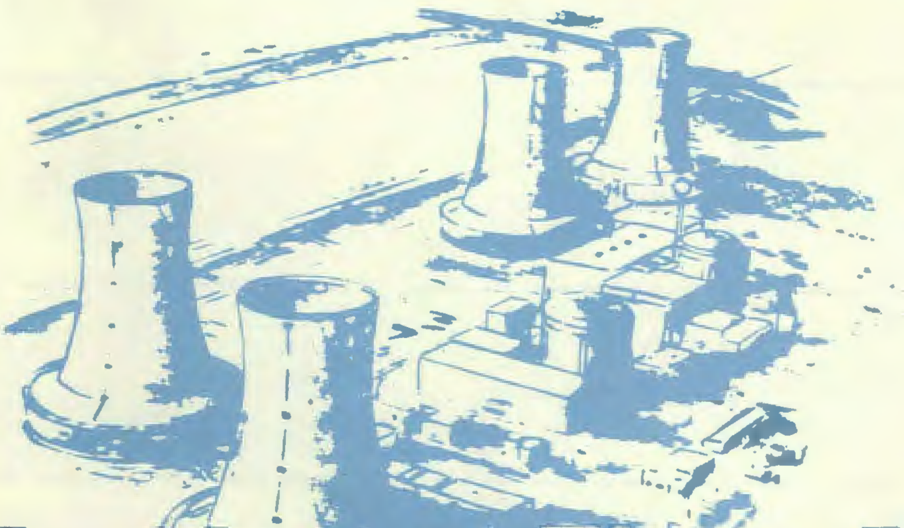


Accident at Three Mile Island

How ORNL Responded

By LARUE FOSTER

Bob Brooksbank, a chemical engineer in ORNL's Chemical Technology Division, was in a meeting on Wednesday morning, March 28, with colleagues at the Nuclear Fuel Services reprocessing facility in West Valley, New York. The topic was operator licensing. The discussion was interrupted by someone appearing in the doorway with the announcement that "there's been an accident at Three Mile Island." Looking back on that morning, Brooksbank recalls that he wondered fleetingly whether ORNL might be called on to assist at the nuclear power plant near Harrisburg, Pennsylvania, if the accident were serious.

The conversation of the group at Nuclear Fuel Services turned to speculation on the nature and causes of the accident and its potential effects, the worst of which, they agreed, would be bad publicity. As the meeting broke up, someone concluded, "That's all we need now—with the industry under fire from critics of nuclear power." Little did Brooksbank know that he and his staff would soon be on the front line preventing hazardous radioactive gases and liquids from escaping the crippled plant.

Back at ORNL, Don Trauger, associate director for nuclear and engineering technologies, was spending the morning at work on a talk to be delivered the following Saturday on the importance of nuclear power as an energy source. He received a call from Ruby Miller of UCC-ND's Public Relations Department advising him that word had just been received of a serious accident at Three Mile Island. He, too, recalls thinking that ORNL might be called on to provide assistance. Within the next few days, about 25 ORNL staff members were indeed involved in onsite technical support effort in the areas of radiation monitoring, chemical engineering, and instrumentation and postaccident diagnostics. They rendered assistance to the Nuclear Regulatory Commission (NRC) and Metropolitan Edison, the utility operator of the crippled Unit 2 at Three Mile Island. Back home in Oak Ridge, more than 50 staff members were mobilized to provide technical assistance and analytical support to the teams already at the plant site.

How ORNL Became Involved

On Friday morning (March 30), utility officials meeting with NRC advisors agreed that the situation looked bleak. Harold Diekamp, president of General Public Utilities (GPU), the holding company for Metropolitan Edison, called up Floyd Culler, president of the Electric Power Research Institute (EPRI) and briefly outlined the situation. "We need help," Diekamp said. "Who are the best people in the business?"

This view of Three Mile Island shows the Susquehanna River in the top left corner, two cooling towers in the top right corner, the electrical substation in the lower right corner, and the turbine building for the crippled Unit 2 reactor in the lower left corner. Labeled buildings are the (1) Unit 2 reactor building, (2) Unit 2 fuel handling building, (3) Unit 2 auxiliary building, (4) cleaning building that now contains EPICOR-II, and (5) trailers where ORNL staff members worked.

Culler, formerly deputy director at ORNL, telephoned ORNL Director Herman Postma, who urged Culler to contact the ORNL staff directly. Before the day ended, a number of ORNL staff members would already be at work, sharing their knowledge and technical expertise, many of them having indeed been called by Culler personally. Other ORNL staff researchers were contacted by NRC officials, who knew from personal experience with the Laboratory staff the special skills available in ORNL's multidisciplinary R&D setting, where advice and technical assistance in many fields could be found during an emergency.

Also on Friday, the "home" team was beginning to mobilize. Realizing that work would continue throughout the weekend, ORNL became part of an on-call communications network set up through the DOE Incident Response Center. A list of radiochemists, instrument specialists, and others was prepared. Calls were to be received by the Laboratory shift supervisor, who forwarded them to coordinators who would determine the response. When the first late-night call came in —a request concerning radiation effects on instrumentation—a team from UCC-ND's Computer Sciences Division was called into action. In fact, Fred Mynatt, director of NRC programs at ORNL, says that most of the requests made through this special communications system were received closer to midnight than any normal time because ORNL's principal NRC contacts were working the night shift at TMI. After response teams were in operation, communications were directly with their NRC or utility counterparts, thereby freeing the coordinators to handle new requests only.

The Oak Ridge Operations Office of DOE immediately endorsed the Laboratory's participation at TMI. An ORO official told ORNL management: "Do whatever is necessary to assist. We'll clean up the red tape later."

Looking back on those hectic days, Dick Egli, deputy assistant manager of DOE's Office for Energy Research and Development in Oak Ridge, recalls: "People like to criticize the slowness of bureaucracy, but in an emergency we can respond quickly. We know that the scientific community recognizes the many experts at ORNL. When Diekamp asked Culler 'Who's the best? ' we knew that ORNL would be needed."

Egli goes on to explain that ORNL and the other national labs can make a unique contribution in times of crisis: "Among the scientific community and the world at large, our national laboratories have special advantages. They have a high level of competence. They can play a purely technical role—be totally objective with no vested political interest. This strengthens their credibility in making assessments and in providing expert advice, especially in times of emergency."

The First Team to Go

By Friday afternoon, the first ORNL team, led by DOE-ORO staff health physicist Bobby Joe Davis, was en route to TMI to do offsite radiological monitoring. Davis

Jim Stokely, (left), Juel Emery, Tom Scott, and Jim Eldridge are Analytical Chemistry Division staff members who worked on radiochemical measurements of the samples sent to Oak Ridge.

was accompanied by members of ORNL's Industrial Safety and Applied Health Physics Division: health physicist Roy Clark and technicians Bill Carden, Bill Johnson, Mitch Conner, and A. C. Butler.

At first, it appeared that the difficulties at the power plant would almost be matched by the frustrations of getting there. United Airlines had recently begun a strike, making scheduled airline connections difficult, sometimes impossible, to arrange. ORNL's travel department stepped in, smoothing the way with chartered service where necessary. In the weeks ahead, the travel department staff worked long hours scheduling reservations, arranging charter flights, and handling complex reimbursements for the staff members, many of whom had to make several trips to the Pennsylvania site, often trading rental cars and motel rooms among themselves as accommodations became more difficult to obtain.

The joint DOE-ORNL team would spend the next week working in 12-hr shifts around the clock, taking air, soil, and vegetation samples in a 10-mile radius of the plant and collecting data on beta, gamma, and background radiation. A similar team from Argonne National Laboratory worked with them. They placed samples in plastic bags on which they recorded the date, time, and location, and then took the samples to NRC's mobile lab at the TMI site. From there, preliminary analyses were sent to the command center some 15 miles away, where officials from the national laboratories, government agencies, and industry would make complete calculations from the field data.

The worst hazard they found? According to Davis: "The biggest environmental hazard for all of us was the cold, rainy weather. We slogged through miles of mud taking samples. But we did encounter another kind of hazard—we almost got shot!"

One night, just after the governor had issued a warning that all looters were to be shot on sight, the team on duty was stopped by a suspicious, very well armed deputy, who wanted to know just why they were roaming around a field behind private homes at three in the morning. "We lost no time in providing a full explanation of our presence," Davis recalls.

On Saturday morning (March 31), another group of ORNL staff members departed for TMI. Jim Eldridge of the Analytical Chemistry Division and Steve Hamley of the Industrial Safety and Applied Health Physics Division left via commercial flight as part of the DOE-ORNL monitoring team headed by Davis.

During their three-day stay, Eldridge observed the community's reaction to potential exposure. "Over 50,000 people left the Harrisburg area," he recalls. "Their concern was based largely on conflicting stories in the print media. On one newsstand were two rival newspapers with conflicting headlines. One warned in huge, bold headlines that a 'Deadly Bubble Perils State.' A rival paper advised that the 'Gas Bubble Is Shrinking.' People just didn't know what to believe." Eldridge had high praise for the balanced reporting provided by area radio stations, which encouraged listeners to maintain contact with neighbors having hearing handicaps and to be ready to render assistance if evacuation became necessary.

The monitoring team used a Thyac-GM survey meter to take direct radiation measurements in the air and to locate and follow the plume from the reactor area. The group's monitoring activities included taking samples of vegetation clippings, soil scrapings from the top ⅛ in., and air samples, using portable monitoring equipment. Because some off-gas venting from the stack had occurred in the hours immediately following the accident, it was necessary to determine whether the surrounding population had

Joe Northcutt is loading a sample of TMI coolant water into a rabbit for irradiation in the Oak Ridge Research Reactor for neutron activation analysis. The process, which involves delayed neutron counting of the irradiated sample, is used to determine the amount of uranium present at the level of parts per billion.

undergone exposure to iodine-131. The results of their work provided state and federal officials with enough information to reassure area residents that their food and water supplies were safe. (Although pregnant women and small children in a 5-mile radius of the TMI plant had been advised by the Pennsylvania governor to evacuate the area for a time, this was done only as a precaution against any potential release, not in response to an already present danger.) The monitoring group also provided information that assisted another ORNL team, led by Bob Brooksbank, whose job it was to contain radioactivity on the site.

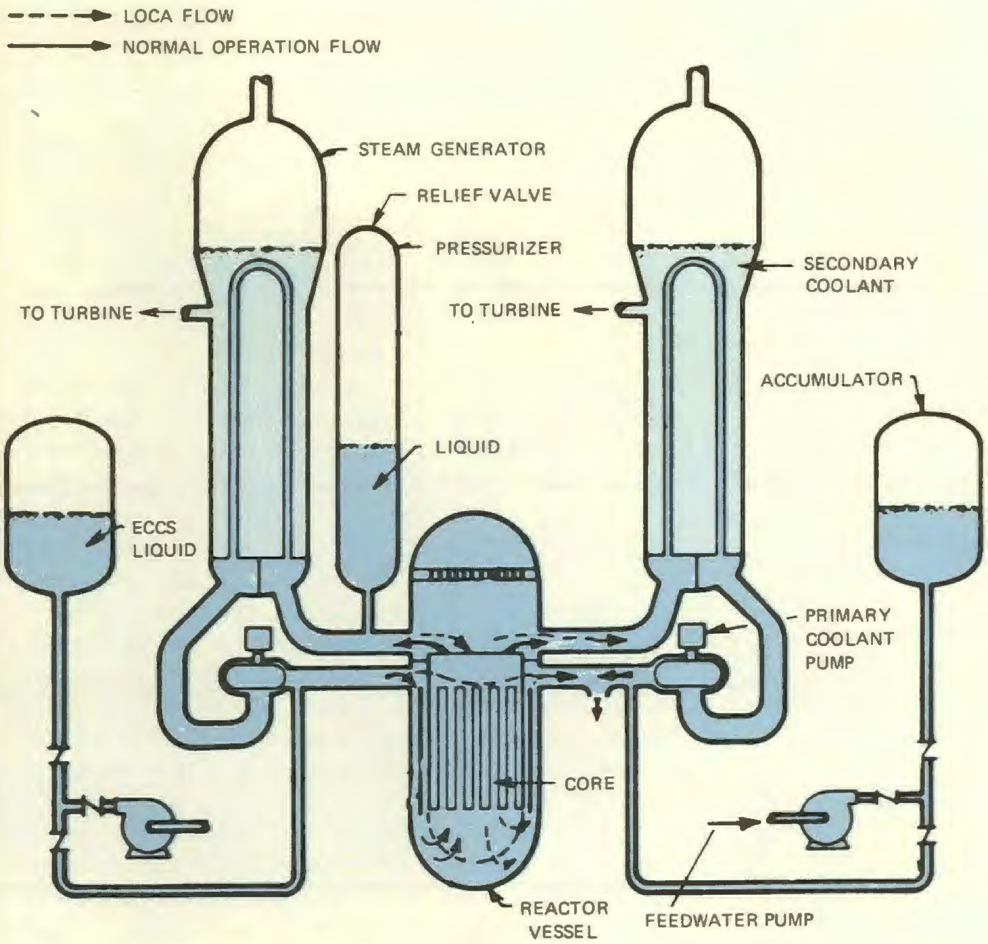
"We have the technology ..."

On Sunday morning, April 1, Brooksbank was in his office catching up on paper work when he received a telephone call from EPRI President Culler, who outlined briefly the immediate concerns of NRC and Met Ed officials at TMI. Listening to Culler's description—"a hydrogen bubble in the reactor vessel ... undetermined quantities of ^{131}I in the cooling water ... problems with effluent control ... areas flooded"—Brooksbank began considering the approaches he could take to the problems. He didn't have to pause before responding affirmatively to Culler's query: "Can you give us the help we need, Bob?" Said Brooksbank later, recalling the conversation, "We have the technology at ORNL needed to solve these problems. I felt confident that we could handle this request."

There was sound reason for his confidence. Over the past three decades, ORNL has developed much of the nuclear fuel reprocessing and effluent treatment technology used in industry. The problems that were occurring at Three Mile Island were of much the same kind that had been anticipated in fuel reprocessing facilities: the need for proper sampling, the provision of adequate storage capacity for waste effluents, and the prevention of release of radioactive iodine to the environment. "At ORNL, we have experience in the development of such processes and safeguards, and our research has given us continuing expertise in radiation monitoring and waste handling," sums up Brooksbank.

As soon as his phone conversation with Culler ended, Brooksbank was back on the line, assembling an ORNL backup team with the needed skills and experience, and arranging for necessary equipment and protective clothing and air transportation. With him went Orlan Yarbro and Jim Snider of the Chemical Technology Division to work on the problems of off-gas and waste water management. They were joined a few days later by Bill Shannon, also of the Chemical Technology Division, who provided assistance to plant operators in the cleanup of contaminated areas. Industries generally rely on private firms that specialize in handling minor spills and contamination. At TMI, Shannon was able to provide expert assistance to plant operators in safety precautions and related procedures in handling high levels of activity and decontamination.

Brooksbank and Yarbro arrived first and reported in at command headquarters. They quickly organized a waste management team to deal with the crucial problems at hand. "Our first concern," Brooksbank said later, "was the presence of radioactive



This schematic of a pressurized water reactor shows the feedwater pump and pressurizer relief valve that caused trouble in the early hours of the accident at Three Mile Island. A discussion of the sequence of events following the initial incident appears on the next two pages.

iodine, which poses a severe hazard to humans if released to the environment." Iodine-131 is of particular concern because it can deposit on grass and enter the human food chain through cow's milk. If ingested by people, ^{131}I concentrates in the thyroid gland where it may cause cancer. If pregnant women are exposed to ^{131}I, there is an increased risk that their babies could develop hypothyroidism, a condition which, if undetected and untreated in the first days after birth, can produce mental retardation or abnormally sluggish speech and movement. As it turned out, only a few samples of milk were found with detectable levels of ^{131}I—maximum levels of about 50 picocuries/liter. During the 1976 fallout from the Chinese bomb, milk samples in the Harrisburg area had up to 1000 pCi/liter of ^{131}I. Corrective action is taken when iodine levels in milk exceed 12,000 pCi/liter.

The immediate goal of Brooksbank's team was to minimize the release of ^{131}I to the environment. To achieve this, the researchers added sodium hydroxide and thiosulfate to the cooling water system. These compounds stabilize ^{131}I, which in water may be highly volatile (i.e., it vaporizes easily out of water and becomes airborne). Iodine-131 has a half-life of only eight days, so if it can be contained for a few months, natural decay solves most of the iodine problem.

Brooksbank was then alerted to another problem by Yarbro, who informed him that the filter trains needed replacing at the auxiliary and fuel handling buildings where radioactive exhaust gases were a serious problem. The filter trains constitute an enormous system of charcoal-filled compartments through which air is filtered before venting up the stacks. Iodine-131 is adsorbed onto the charcoal, which prevents it from escaping to the environment. Brooksbank describes the difficulty: "We have learned at ORNL that such filters are 'dead'—that is, desensitized—after a year of operation, regardless of whether any iodine passes through them. Forced air flow alone will deplete the filters' adsorptive qualities. Furthermore, organic iodides could also form under TMI's special conditions."

Brooksbank knew that complete filter replacements were needed immediately. In most organizations, a request for such a massive undertaking, both in terms of personnel and money, requires a period of months and numerous approvals through an orderly chain-of-command. But time was one commodity Brooksbank did not have. He went straight to GPU President Diekamp and explained the potential hazard. Diekamp moved into action at once to locate replacement filters. Within hours, a new set of filter trains that had been awaiting installation in a California power plant were en route to TMI by Air Force cargo transport.

Installation of such a filter system is no small engineering feat, even under the best conditions. The system fills a

(continued on page 8.)

An Improbable Set of Circumstances

The worst nuclear accident in American history was triggered by a series of valve problems, setting off a chain of mechanical and human errors—an improbable set of circumstances. Up until that point, the pressurized water reactor at Three Mile Island (TMI) had been generating 880 MW of electricity supplied to residents of four counties. But on Wednesday, March 28, the feedwater pump that forces hot water in the secondary loop from the condenser to the steam generator stopped. Two auxiliary pumps switched on but could not pump water since plant operators had inadvertently shut off their valves several days prior to the accident—a violation of the facility's technical specifications. As a result, the turbine and secondary heat-removal system shut down, denying the primary coolant system a place to dump its heat. On a signal from increasing pressure in the primary system, the fission-quenching control rods (made of boron, a neutron-absorbing element) dropped amidst 36,816 fuel rods sheathed in a zirconium alloy known as Zircaloy and filled with uranium dioxide fuel pellets.

Although the reactor had shut down automatically, the fuel core continued to generate heat at a reduced rate due to radioactive decay of fission products. Thus, the temperature and pressure of the water in the primary reactor system continued to climb as the water picked up the fuel core's decay heat but was unable to transfer it to the secondary loop which was rapidly boiling dry. When the escalating pressure in the primary system reached 2350 psi, a relief valve designed to maintain a specific level of pressure in the reactor's cooling system opened on the primary system's pressurizer. The relief valve stuck, failing to close when the pressure returned to 2300 psi. The control room indicator showed that the relief valve had closed, and subsequent checks of the temperature in the pipe downstream from the valve did not alert the operators to a possible problem because of a history of slightly elevated temperatures from valve seepage. Therefore, the operators did not immediately close the block valve which would override the relief valve and stop the pressure and water loss.

The stuck valve, essentially equivalent to a small pipe break, allowed primary water to discharge into the quench tank, which overflowed when a disc ruptured and flooded the floor of the domed concrete containment structure. As the water poured out the valve, the reactor pressure and water level dropped. At about 1600 psi, the reactor pressure drop activated the three pumps of the high-pressure emergency core cooling system, which forced water into the reactor.

With the pressure drop, some of the water turned to steam, causing expansion in the volume of the two-phase coolant. An operator prematurely shut down the emergency core cooling system due to misinterpretation of the rising coolant level indication in the pressurizer tank. Unaware of the steam pressure and a water trap in the pressurizer line that held water in the elevated pressurizer tank, the operator interpreted the high pressurizer level as indicating that the reactor pressure vessel was full of water. But later the core was uncovered for several hours, causing overheating and extensive damage to the core and the release of fission products to the primary system.

Under the stress of the emergency, plant operators failed to notice that a sump pump in the containment structure's basement—which normally pumps relatively clean water into holdup tanks in an auxiliary building in the event of an overflow—was transferring the now-contaminated water to the auxiliary building. This building, which houses much of the emergency cooling system, was not designed to contain such high-level radiation. The sump pump continued to run even as the tanks overflowed, allowing the contaminated water to flood the auxiliary building's floor. The water flooding the building released radioactive gases through the ventilation system to the environment. At the auxiliary building vents where gases such as xenon, krypton, and some iodine escaped through filters, radiation levels of 1200 millirem/hr were measured.

ORNL teams were dispatched to the TMI site to measure and minimize the release of the radioactive gases to the surrounding population—about 600,000 people in a 10-mile radius. Based on measurements taken in the area, the Nuclear Regulatory Commission (NRC) estimated that area residents had received radiation doses less than two chest x-rays or the additional background of living in Denver, Colorado for a few months. The U.S.

Department of Health, Education, and Welfare (HEW) estimated that the radioactivity released in the Harrisburg area would result in one additional fatal cancer and one nonfatal cancer. The expected number of spontaneous natural cancers is 120,000 for this population of 600,000; therefore one may judge that the accident resulted in no detectable health effect.

By Wednesday night, the back-up valve had been closed, and the reactor was stabilized. The system was filled with water, the pressure was maintained at 1000 psi, and one circulation pump was operating. However, on Friday, March 30, a new crisis developed—a bubble (possibly due to steam oxidation of the Zircaloy fuel cladding) was believed to have formed at the top of the reactor vessel. The well-known tendency of high-temperature steam to react with zirconium and the resultant release of hydrogen and large quantities of heat may have caused the formation of a bubble that contained hydrogen, steam, and fission products. The bubble at Three Mile Island was worrisome for two reasons: (1) if the bubble contained hydrogen (which would react with oxygen if oxygen were present in the reactor primary system), it could cause an explosion that could rupture the system and release radioactivity to the environment; and (2) of even more serious concern was the possibility that the bubble might interfere with water circulation (if the system pressure dropped), thus permitting an additional uncovering of the fuel. The worst and also most improbable case (the scenario that fascinates the news media and was described in the recent motion picture, "The China Syndrome"), postulates a core meltdown in which the hot fuel would melt through the reactor vessel walls and containment structure and burn into the earth beneath.

ORNL teams were sent to assist in determining the position of the bubble and decreasing its size, and a sample of cooling water from the reactor's primary circuit was shipped to ORNL for analysis to ascertain the fission product activity level and to determine if the water contained a significant concentration of uranium. Over the weekend following the initial incident, much effort was devoted to bleeding off the hydrogen, which had stymied attempts to reduce primary system pressure so that more appropriate systems could be called upon to cool the core.

The hydrogen was removed by spraying water from the primary circuit into the steam region of the pressurizer, thus degassing the water and accumulating hydrogen in the top of the pressurizer. From time to time, the relief valve was opened to vent the hydrogen into the reactor containment building. Hydrogen recombiners were added to the containment vessel to combine hydrogen with oxygen from the containment atmosphere to form water, thus removing the hydrogen hazard. By Monday, April 2, the bubble crisis was over.

By then, it had been determined that the fuel core had been damaged by overheating. It was estimated that a third of the core's Zircaloy cladding was oxidized. As the embrittled cladding disintegrated, about 30% of the volatile fission products were released into the primary circuit from the 12-ft fuel rods, and some fragments of uranium dioxide fuel pellets might have been in rubble caught in the intact fuel pins or core support areas. Some assemblies might have been blocked by debris causing poor circulation of the cooling water. This created hot spots and caused concern that localized core boiling might cause further core damage. Another ORNL team dispatched to the accident scene monitored the reactor for loose and drifting parts and other signs of loss of mechanical integrity as well as evidence of core boiling. No indication of these maladies was found. Natural convection cooling was achieved on April 28.

Despite the severity of the accident, there was mounting evidence that the temperatures attained in the fuel core had been less than the melting point of uranium dioxide, which is 4800°F. The peak core temperature during the "dryout" period was believed to be in the range of 1800 to above 3500°F, high enough to cause melting as well as oxidation of the Zircaloy cladding. Analysis of the water sample at ORNL showed that the primary coolant solution contained virtually no uranium; this, however, does not preclude fuel melting because uranium is not very soluble in water. The silver lining in the gloom surrounding the Three Mile Island accident was the fact that a major accident involving severe core damage was of no hazard to the public.—*CK*

Joel Carter, standing, and R. C. Bryant watch the data output from the spark source mass spectrometer (foreground) on which elemental analysis was performed on the TMI primary coolant water sample.

warehouse-sized room and normally takes months to install, yet in this crisis, crews on 24-hr shifts completed the task in a short period, with Brooksbank and his co-workers from ORNL monitoring the system throughout installation.

In continual touch with the radiation monitoring team from Oak Ridge, Brooksbank learned that test data on composite samples taken in the vicinity had shown no ^{131}I or other fission products. The report was heartening, but the emergency installation of new filters was still necessary. "We couldn't afford to take any chances," Brooksbank said. "We took every precaution to protect the downwind population. The reactor core was not yet completely stabilized." He added that the "utility was fully cooperative and willing to do whatever was necessary to ensure the safety of the surrounding communities."

Even while installation of the new filter trains was still under way, Brooksbank and his team turned their attention to the problem of liquid effluent control. Because ^{131}I has such a short half-life, storage of the contaminated water appeared to be the safest procedure. This was complicated by the sheer volume of water in the flooded auxiliary building. Despite the removal of ^{131}I by natural decay, considerable processing was going to be needed on the water to meet guidelines set by the Environmental Protection Agency (EPA) for environmental release. Additional water used during subsequent cleanup operations would also have to be processed. Holding tanks were ordered to increase onsite storage capacity. Snider and F. E. Harrington of the Chemical Technology Division responded to this demand by providing conceptual designs for the storage facility.

The team began formulating plans to deal with chemical contaminants in the water including fission products such as radioactive cesium and strontium. The sodium thiosulfate, added to stabilize ^{131}I, and large quantities of boron, added to the water to prevent the reactor from achieving criticality, would all have to be removed. There was also considerable miscellaneous debris—paint flakes and the like—resulting from the effects of high temperatures and pressures in the reactor containment after the accident. This would also have to be removed so that the water could meet NRC and EPA standards before being discharged into the Susquehanna River.

Basically, three types of radioactive water were generated from the TMI incident—low-activity water containing minute amounts of cesium-137, intermediate-level water containing greater amounts of ^{137}Cs and held in the auxiliary building tankage, and very radioactive water (with an order of magnitude more ^{137}Cs than in the intermediate-level water) contained in the reactor building floor and in the primary loop circuit. The process designed for cleanup of the low-level water was EPICOR-I, a commercially available system employing standard mixed-bed organic ion-exchange resins and bed filters. This system functioned well, and discharge-quality water was produced within technical specifications, according to Brooksbank.

The use of a modified process, called EPICOR-II, was selected for use in cleaning up the intermediate-level water in the auxiliary building. This process is aimed at the specific removal of ^{137}Cs, ^{131}I, ^{90}Sr, and other fission products leached from the reactor fuel. Because the resultant concentration of fission products from this process poses the problem of high radiation levels, along with the potential of further release to the environment, a well-contained facility was mandated. Using knowledge acquired in designing radiochemical plants, Snyder provided conceptual design assistance to the architect-engineers on the site to permit this process to be conducted in a safe manner. The modified process, recently reviewed and approved by NRC, calls for the remote operation of all equipment, with independent off-gas handling of process effluents.

The treatment of high-level radioactive water represents a

Oak Ridge National Laboratory provided onsite technical support in the areas of radiation monitoring, chemical engineering, and instrumentation and diagnostics in the weeks following the Three Mile Island accident. Twenty-five staff members went to the site to give assistance, and another 50 Laboratory scientists and engineers worked at Oak Ridge to provide technical support to the onsite teams at the request of the NRC and the GPU. In all this, more than 75 people have been involved, most of whom are listed below:

ONSITE SUPPORT

Radiation Monitoring, R. L. Clark, leader of the team: A. C. Butler, W. D. Carden, M. L. Conner, B. J. Davis (DOE-ORO), J. S. Eldridge, S. A. Hamley, W. M. Johnson, B. A. Powers, and J. E. Smith.

Chemical Engineering, R. E. Brooksbank, leader: D. O. Campbell, C. A. Burchsted, E. D. Collins, F. E. Harrington, L. J. King, W. A. Shannon, J. W. Snider, and O. O. Yarbro.

Instrumentation and Diagnostics, R. C. Kryter and D. N. Fry, leaders: S. J. Ball, J. B. Bullock, R. M. Carroll, T. E. Mott (TEC), J. C. Robinson (TEC), R. L. Shepard, W. H. Sides, C. M. Smith, and G. L. Zigler (SAI).

AT-HOME SUPPORT

Cooling of Disrupted Core, M. H. Fontana, leader: J. F. Dearing, P. W. Garrison, and S. Rose.

Analysis of Fuel and Cladding Effects, D. O. Hobson, leader: R. A. Lorenz and R. E. Pawel.

Chemical Analysis of Water Samples, W. D. Shults, leader: J. A. Carter, W. H. Christie, L. T. Corbin, A. R. Crook, J. F. Emery, G. I. Gault, L. R. Hall, L. M. Jenkins, W. R. Laing, L. Landau, E. G. Miller, W. R. Musick, K. J. Northcutt, H. A. Parker, B. Philpot, S. H. Prestwood, J. C. Price, H. C. Smith, J. R. Stokely, and R. L. Walker.

Radiation Effects and Core Nuclear Analysis, G. E. Whitesides, leader: R. L. Childs, O. W. Hermann, J. R. Knight, J. V. Pace, and R. M. Westfall.

Radiation Shielding and Effects, D. E. Bartine, leader: T. J. Burns, R. L. Childs, W. W. Engle, D. T. Ingersoll, J. V. Pace, and D. L. Selby.

Hydrogen Chemistry, J. R. Buchanan, leader: R. B. Gallaher, G. H. Jenks, W. L. Marshall, G. T. Mays, and R. L. Scott.

Instrumentation and Diagnostics, L. C. Oakes, leader: J. L. Anderson, R. S. Booth, F. H. Clark, R. E. Hedrick (SAI), M. B. Herskovitz, J. T. Mihalczo, P. J. Otaduy, J. R. Penland (SAI), and R. S. Stone.

Chemical Engineering, J. E. Bigelow, F. R. Chattin, R. D. Seagren, and C. E. Waddell.

unique technological challenge because of the presence of fission products in a medium containing high levels of boron and sodium. Water of this nature has never been treated in existing processes within the nuclear industry. Dave Campbell of the Chemical Technology Division was assigned the primary task of establishing a flowsheet for a suitable process. Hot-cell studies of organic and inorganic exchangers were initiated on actual TMI high-level water as a joint venture between the Analytical Chemistry and Chemical Technology Divisions. Because of the tremendous cost and impact of solid shipments necessary for more conventional processes, a series of kinetic column runs were made in the Transuranium Processing Facility (TRU) (under the guidance of L. J. King and E. D. Collins) to establish realistic column conditions.

A firm flowsheet was recently presented, and Campbell, Brooksbank, and other chemical engineers continue to be actively involved in providing technical assistance toward the development of environmentally safe cleanup and disposal procedures for wastes at TMI.

Eavesdropping on the Reactor

Bob Kryter of ORNL's Instrumentation and Controls Division began his involvement with events at TMI on the Friday morning following the accident, *A glimpse of the control room at the Three Mile Island nuclear power plant about a week after the initial incident.*

when he received a call from NRC officials requesting information concerning loose-parts monitoring systems. He and co-workers had completed a report on the subject just a few months earlier, so he had the needed information at hand. That Friday afternoon, Kryter and fellow division members brainstormed about the probable monitoring conditions at the plant and the options for assessing the size and location of the bubble inside the reactor pressure vessel.

By Tuesday afternoon (April 3), Kryter and co-worker Dwayne Fry were called to TMI to provide assistance in noise monitoring of the conditions inside the reactor. Armed with cables, oscilloscopes, amplifiers, and a portable noise analyzer, the pair began work.

Their task was to provide an assessment of conditions inside the reactor vessel through taps into a number of existing plant sensors. In effect, they would be "listening in" to any unusual noises in the reactor—alerting them, for example, to possible disintegration of the core or to coolant that was boiling, which would warn of continuing high temperatures. The normal sensing equipment that would provide this information to plant operators via control board circuits was either not sufficiently sensitive for this purpose or was not working. When the containment and auxiliary building floors were flooded, some of the delicate sensors located at floor level ceased to operate; they had not been designed to function under water.

Explains Kryter: "Our work was complicated by the fact that reactors have individual as well as generic noise characteristics according to their manufacturing specifications. Thus, 'normal' sounds can be recognized only if the exact nature and brand of the equipment, including the plant sensors, is known. As parts wear out during use, they are often replaced by a different brand. We had no prior experience with the TMI unit, and we didn't know just what to monitor for until we got to the site and were given the current equipment specifications and brand identities."

The monitoring team, of which Kryter and Fry were a part, found no indication of either localized core boiling or structural degradation of the core.

The Backup Teams

While teams of ORNL staff members were busy providing expert assistance at TMI, a large contingent of Laboratory researchers were equally busy at ORNL providing backup support. Mynatt, who had been in frequent touch with the NRC in the days following the accident, recalls numerous telephone calls from NRC staff members requesting data analyses, statistical estimates, and other information from ORNL.

"Frequently, these people needed the answers within minutes," Mynatt said. "There was no time for running complex computer programs. We used hand calculators and sent answers back right away, then backed up our figures with computer output in the hours that followed."

Other calls came to W. D. Shults, director of the Analytical Chemistry Division, who was first contacted the day following the accident with the query: "Can you analyze a sample of water from the reactor vessel?" Shults said the answer was easy: "Yes, if you can get it to us." That sample was not obtained because of radiation conditions. Not long after, Shults received another query: "Can you analyze a sample of water from the auxiliary building?" This answer was again affirmative, and this time, the sample came.

"There was a little communication problem concerning this sample," Shults recalls. "When we were finally notified that it was on the way, we were told that it would be in a 50-gallon lead container. Although I had a team waiting at the airport, I didn't know how we could possibly get anything so heavy to Oak Ridge without special heavy equipment. Fortunately, when the sample arrived, it was inside a small lead container which was inside an ordinary 50-gallon drum."

A spark-source mass spectrometer, especially adapted to analyze radioactive samples, was used to identify all elements present and to determine their levels of concentration. Thermal-emission mass spectrometry was used to obtain the isotopic compositions and quantities of uranium and plutonium. A highly sophisticated technique developed at ORNL was used in this latter work. Resin beads about the size of sugar grains are used to adsorb uranium and plutonium from solution. A single bead is then analyzed in the mass spectrometer. The results obtained from these analyses demonstrated that the primary cooling water had been in contact with the fuel; the isotopic compositions of uranium and plutonium agreed very well with those values predicted from the reactor's operating history.

"The results of this work were incredibly accurate," says Shults. "The analysis provided a quantitative accuracy to parts per billion—all out of just one tablespoon of water." The technique, developed at ORNL by Joel Carter and others, is now being taught to other laboratories (see "A New Technique for Safeguarding Nuclear Materials," ORNL *Review,* Fall 1979).

"A Vital Kinetic Force"

On June 11-12, Thomas Pigford, a member of the President's Commission on the Accident at Three Mile Island, visited ORNL and commended the Laboratory on its role in bringing the reactor under control. Some of the information Pigford obtained in his discussions with ORNL employees may be incorporated in the commission's report, which is to be issued in October.

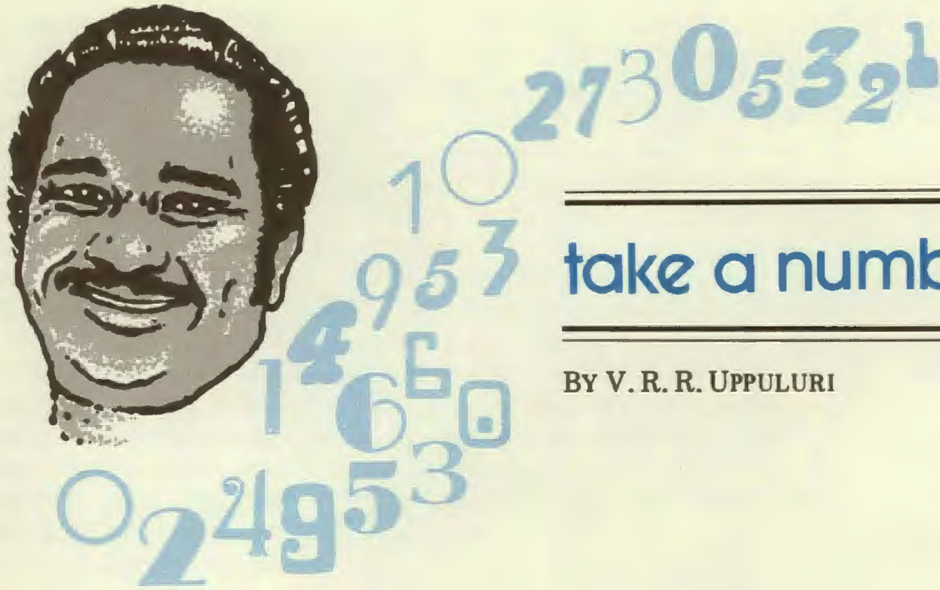
More than 75 members of the ORNL staff have received certificates praising them for the technical assistance and support they provided in the aftermath of the TMI accident. Virtually everyone at ORNL followed with great interest the sequence of events after the initial incident, as indicated by the fact that ten days after the accident, two ORNL auditoriums were packed for Mynatt's lecture on what had happened and how ORNL was helping. In that talk, replayed on videotape the following week, Mynatt called for better postaccident instrumentation, more computer aids and improved instruments for operators, and recognition of the possible need to have nuclear plant operators be NRC employees who would be better trained and dedicated first to public safety rather than to the production of electricity.

Associate Laboratory Director Don Trauger was another ORNL employee who was much in demand to give his views on the TMI accident to professional colleagues as well as to the news media. In a speech before the Chattanooga Engineers Club on June 4, Trauger presented the accident in optimistic terms, noting that no fuel melting occurred, safety systems and containment functioned reliably, occupational radiation exposures were within annual limits set by the federal government, damage was confined to the reactor core, and much equipment may be reusable following decontamination. "The greatest direct public consequence," Trauger said in his speech, "is the loss of electricity and the cost of replacement power."

LaRue Foster, editor of the Lab News, *came to ORNL in 1976. Since early 1978 she has been technical editor of the* Review.

Over the next few months, ORNL staff members will continue to be involved with Three Mile Island. Cleanup and disposal of wastes, more analytical chemistry tests, and a complete sifting and ordering of all the data about events surrounding the accident will take place. The technology developed at ORNL has enabled the industry to have information not available through other sources and to make informed decisions about the fate of the reactor and about protective measures to be taken for the community. As a result of this input from the pool of ORNL experts who participated in the emergency, there will doubtless be a number of studies and plans for the future operation of nuclear power plants—plans in which ORNL will probably play a significant role.

W. D. Shults effectively sums up the experience and the special response that the Laboratory provided: "There are many individuals at ORNL with great expertise in highly specialized areas. Often this talent is waiting—an untapped reservoir until it is needed in a crisis. When called upon, these people act with energy and eagerness. We can translate that potential energy on tap into a vital kinetic force. None of us want another Three Mile Island—but the special team spirit generated at ORNL in those crucial hours has helped us to realize again the unique contributions of a national laboratory." ornl



take a number

By V. R. R. Uppuluri

High Card Point Count in a Bridge Hand

Consider an ordinary pack of 52 playing cards. Let us define the value of an ace to be 4, of a king to be 3, of a queen to be 2, of a jack to be 1, and any other card to be 0. For a bridge hand of 13 cards, the sum of the values of the cards in the hand is known as the high card point count, or the value of the hand. Clearly, the value of a hand will lie between 0 and 37. A bridge hand with no jacks, queens, kings, or aces will have a value of 0; and a bridge hand with 4 aces, 4 kings, 4 queens, and a jack will have the value $4\times4 + 4\times3 + 4\times2 + 1 = 37$.

If the cards are shuffled well and dealt at random, one may ask for the theoretical distribution of the values of a bridge hand. Let x denote a typical value and $f(x)$ denote the probability with which this value appears. A table of this probability distribution shows that each of these probabilities is low, although the expected value of a hand is 10 with standard deviation equal to 4.13. This table is useful to individuals who are interested in rare events and is presented here at the suggestion of a friend. For related problems, one may refer to the book *Bridge Odds Complete*, by C. H. Frost, Aegean Park Press, Waltham, Massachusetts (1977).

Probability distribution of high card point count in a bridge hand

x	$f(x)$	x	$f(x)$	x	$f(x)$
0	3.639×10^{-3}	13	6.914×10^{-2}	26	1.167×10^{-4}
1	7.884×10^{-3}	14	5.693×10^{-2}	27	4.907×10^{-5}
2	1.356×10^{-2}	15	4.424×10^{-2}	28	1.857×10^{-5}
3	2.462×10^{-2}	16	3.311×10^{-2}	29	6.672×10^{-6}
4	3.845×10^{-2}	17	2.362×10^{-2}	30	2.198×10^{-6}
5	5.186×10^{-2}	18	1.605×10^{-2}	31	6.113×10^{-7}
6	6.554×10^{-2}	19	1.036×10^{-2}	32	1.719×10^{-7}
7	8.028×10^{-2}	20	6.435×10^{-3}	33	3.521×10^{-8}
8	8.892×10^{-2}	21	3.779×10^{-3}	34	7.061×10^{-9}
9	9.356×10^{-2}	22	2.100×10^{-3}	35	9.827×10^{-10}
10	9.405×10^{-2}	23	1.119×10^{-3}	36	9.449×10^{-11}
11	8.945×10^{-2}	24	5.590×10^{-4}	37	6.299×10^{-12}
12	8.027×10^{-2}	25	2.643×10^{-4}		

On March 7, 1979, representatives of Edgerton, Germeshausen, and Grier (EG&G) visited ORNL to present the company's capabilities for subcontract work. With them came their chief executive officer, B. J. "Barney" O'Keefe. As president and chairman of the board, O'Keefe serves as a director of Boston Edison Company, John Hancock Mutual Life Insurance Company, Bird-Johnson Company, LFE Corporation, and New England Merchants National Bank. He serves on the board of directors for the American Nuclear Energy Council, the National Association of Manufacturers (vice chairman), the Greater Boston Chamber of Commerce (past president), the Family Counseling and Guidance Centers, Inc., and the Associated Industries of Massachusetts. He is a trustee of the Lahey Clinic Foundation and of the Museum of Science in Boston. In 1976, he received the Business Statesman Award from the Harvard Business School Association and a Corporate Leadership Award from the Massachusetts Institute of Technology. It is not a custom of the *Review* to publish talks by speakers from outside the Laboratory, but Mr. O'Keefe's words made such an impact on those who heard them that his permission was sought, and granted, to give them wider exposure. It was agreed that this particular side of the energy debate is seldom articulated as eloquently.

The Politics of Energy

By BERNARD J. O'KEEFE

The United States currently uses about 40 million barrels per day oil equivalent, or 80 quadrillion Btu of energy. With oil at the spot price for Saudi Arabian crude at $12.00 per barrel,* natural gas at $2.00 per 1000 cubic feet, and coal at about $40.00 per ton, primary energy costs are a little more than $2.00 per million Btu, or $2 billion per quad. Total annual primary energy costs are therefore

*By the time this article was being prepared for press, OPEC had announced an increase in crude to $23.50 per barrel.

"For the first time in the history of our country, the next generation cannot look forward to a higher standard of living than their parents had."

in excess of $160 billion. With a gross national product (GNP) of about $2 trillion, energy to a first approximation is about 8% of the GNP, a very large number indeed.

In the past five years, real costs of energy have just about doubled—60% of which are due to the quadrupling of imported oil prices, 20% of which are due to environmental costs, and 20% of which are due to increased domestic recovery costs. With energy at 8% of the GNP, a doubling of the cost means that we have had a GNP deflator of about 4%. In "bread and butter" terms, the material standard of living of the average citizen of the United States has been decreased by 4% from what it would have been had 1973 conditions prevailed. This can be attributed to the Organization of Petroleum Exporting Countries (OPEC), to increasing domestic scarcity, and to the social cost of environmental improvements that have little short-term payback.

The intrusion of OPEC is new on the American scene, but scarce resources and sociological costs are not. From the days of diminishing buffalo herds and the scarcity of whale oil for lamps, the United States has dealt with resource scarcity and has overcome it. Similarly, sociological improvement has been at the root of our national culture from child labor laws to shortened work weeks, to free education, to welfare, and now to the environment. In the face of these increased costs throughout history, we have doubled our material standard of living each generation by technological innovation and increased productivity. America has truly been the land of opportunity.

Changed Trend

Unfortunately, in the last decade technology has become suspect, and productivity improvement has been cut by a factor of 3 from 3.8% to 1.2% per year. The result is that the real standard of living of the American citizen has actually decreased during the last five years. *For the first time in the history of our country, the next generation cannot look forward to a higher standard of living than their parents had.* This is the political problem with respect to energy.

We all know that domestic energy is plentiful. We have enough coal to last hundreds of years and 150 years' supply of energy in the ^{238}U breeder reactor fuel that has been discovered, mined, purified, and paid for and that is currently lying idle. We have more oil trapped in shale within a 25-mile radius of Rifle, Colorado, than has been discovered in the whole Middle East, and I could go on with tight gas supplies or such things as Chattanooga shale. The trouble with any current solution to the energy problem is price. Anything we do in the short term will raise the price of energy, and that is politically devastating. That is why the current energy legislation is such a mess and why knowledgeable politicians consider energy a liability and want no part of it. One congressman said to me, "Mr. O'Keefe, I understand what you're talking about. I understand what needs to be done. However, if I take a firm stance for the long term benefit of my constituents, it will be 12 years before they appreciate what I've done for them, and in that period of time, Mr. O'Keefe, I will have been defeated for election six times."

The executive side of the problem is just as bad. Washington's approach to the economy is to fight the last depression, just as the classic military approach is to plan for the last war. Washington is permeated with the Keynesian economics of stimulating demand rather than encouraging supply. Price controls do nothing to encourage supply and do everything to stimulate demand. Our present policy of holding down domestic oil prices while paying world prices to OPEC is mind-boggling in its absurdity. I see nothing in the near future, especially with current inflationary pressures, that will change that policy. In a word, the political prospects for energy improvement in Washington are bleak.

At the state level the problem is worse. Control of energy prices in most states is in the hands of a public utility commission whose orientation is, by statute, short term. Public utility commissions are structured to allocate a return on investment for existing facilities and have no provision for considering new capital investments and the return on those investments. Consequently, there is no mechanism in the state regulatory process for considering long-range investments and new

"... the nuclear power industry will be out of business in two years unless we solve two problems, neither of which has much to do with technology."

plant commitments which must extend well beyond a decade. Governors, most of whom have four-year terms, are extremely vulnerable to short-term pressures. They do not want the prospects of pollution from new power plants and tend to put off such new plants until after election, which is never more than four years away. Furthermore, governors are very sensitive to states' rights and react with horror to prospects of their states' being the nation's garbage dumps for nuclear wastes or other noxious evils.

Specific Problems

But enough of the generalities. Let's talk about specific energy development problems, particularly nuclear power and the present generation of light-water reactors. In my opinion, the nuclear power industry will be out of business in two years unless we solve two problems, neither of which has much to do with technology. The first is financial; the second is political. The financial problem comes from the high cost and long delay time of building nuclear power plants. A typical 1000-MW plant costs more than a billion dollars and takes ten years to build and get on line after the preliminary permits have been authorized. Back when power plants cost $200 per megawatt, they took three years to build, had a guaranteed market, and had relatively straightforward financing. During those times a body of regulatory practice built up whereby the consumer was not required to pay for new capital equipment until it was producing energy. Even interest on the borrowed money was excluded from the rate base.

To placate investors and bond-rating agencies, an accounting fiction known as Allowance for Funds Used During Construction (AFUDC), was allowed in most states. Under this accounting rule, interest costs were capitalized and were reported into earnings as if they had been received, thus artificially inflating earnings. This used to amount to about 10% of a utility's earnings. Under present circumstances, by the time a plant is on line AFUDC can amount to 90% of earnings, with only 10% consisting of actual cash flow. Under these conditions, investors will simply not loan the money. It's as though Union Carbide or EG&G were given a $100 million-per-year, ten-year contract with no funding, where the customer says, "Come back in ten years and we'll tell you when we'll pay you the money, how we'll pay it to you, and what rate of return you'll receive for your efforts." No way is anyone going to invest under those circumstances.

An alternative financing scheme is known as construction work in progress (CWIP), where interest is included in the rate base and cash is received by the utility; however, this violates the standard rate-making procedure and is viewed as a hidden tax by the public, especially by the news media. The governor of New Hampshire was defeated on this issue last November, and I can assure you no utility will be authorized by CWIP in 1979. Politically the issue is straightforward. How can you convince a voter who is worrying about the next week's payment on his automobile loan that he will be better off in 1985 if he pays more for his electricity today. You can't, but the problem must be solved.

The next item is waste disposal. For two decades we have been telling the public that waste disposal is technically solvable, but we are further removed from agreement on the best solution than we were 20 years ago. We continue to consider waste disposal as a technical problem when it's not at all. It's a political problem. Because of the confusion and delay, there are only two states in the union that are likely to permit permanent storage—and one of them is *not* New Mexico. I doubt if we shall ever see the day when a millicurie of permanent radioactive material goes anywhere near the Carlsbad Caverns. That issue is dead politically. Only Nevada and the state of Washington are political possibilities, and I know from close association that Nevada is on the edge. Forget about federal sovereignty. States have all kinds of ways to deny siting permits, waste permits, and environmental clearance. A state bureaucracy is immovable when it digs in its heels. The issue would be tied up in the courts for years. I plead with those of you in a position to influence policy to pick the location *first* and then worry about the technology.

A third factor is the economic impact of alternative sources of energy. For example, to the extent that solar energy ever be-

"New energy sources will be expensive. The public will resist the costs, and the politician who faces the problem squarely will be voted out of office."

comes meaningful in the overall energy picture, the formidable question of standby or backup energy supply comes into play. For most of the country, gas pipelines, nuclear or fossil power plants, and oil or coal supply and distribution systems must be available when the sun is not shining. Most of these standby systems have very high fixed costs. If solar heating systems, especially photovoltaics, were economically available today, I predict we'd be a decade in the courts with enormous political unrest before we could resolve who would pay for what. I don't want to go into the problems of coal because, in addition to the financing and waste disposal difficulties of nuclear energy, there are massive questions of unions and transportation systems and environmental problems of the first order.

The Prospects

All this comes back to my central thesis. New energy sources will be expensive. The public will resist the costs, and the politician who faces the problem squarely will be voted out of office. The political holding action will be more government subsidies, bigger deficits, and increased inflation. I think that's what we're going to have because the alternative of recession and unemployment is even more politically repugnant.

What can we do about all this? Very little, I'm sorry to say, in the short run; but there are avenues of approach for the longer term. The first thing we should look at is the body of environmental, health, and safety laws. Most of these laws were passed at a time when the technological solutions looked simpler than they are, a common mistake of those who feel that technological developments can be mandated. The effects on the economy and energy efficiency were very much underestimated. Future generations will look back at us incredulously and wonder how in the world, with all the worries facing our civilization, we became entangled in the minutiae of saccharin, cyclamates, and snail darters. It's time for a new look at the sociological costs of those who would protect us from ourselves.

But some of these sociological costs and some of the costs of diminishing resources must be met. The primary long-range solution is the classical one for our country—technological innovation and productivity improvement. We must find mechanisms to shorten the time span for the introduction of new technologies. We must revise our tax policies to encourage venture capital and permit rewards for innovation consistent with the increased risks in today's society. A very important mechanism for progress is a stronger relationship between the national laboratories and industry. The concept of technology transfer is probably the most important concept in the Department of Energy's philosophy. The national laboratories are an unparalleled resource for technological innovation. American industry is skilled in the mechanisms by which these innovations are brought to the marketplace in an efficient, effective, and productive manner. Industry cannot attempt to duplicate the resources of the laboratories. The laboratories cannot, and should not, attempt to make the judgments and take the risks required to be successful in a free market.

However, technology transfer is not simple. Innovators by nature have to be somewhat visionary, and they become frustrated when their ideas are not quickly understood and accepted. Cognizant government officials must concern themselves with the problem of unfair competitive advantage if one company is given preference over another. Industry inherently likes to minimize risk and be paid for everything it does, and therefore will want the government to support programs to the point at which economic success can be guaranteed.

In a real sense, these are two different worlds—one where scientific improvement is the ultimate reward and the other where success, but not job satisfaction, is measured primarily in financial terms. I live in both these worlds and find each of them fascinating and stimulating. I am confident that they can work together more effectively. To the extent that we can achieve our mutual objectives of technological innovation and increased productivity, we can absorb the increasing costs of economic scarcity and sociological progress while while still providing the American citizen with the prospect of improvement in his material lot, which is the basic heritage of our American tradition.

information meeting highlights

Fusion Energy, April 2–3

Pellet Fueling of Tokamaks

For a tokamak fusion reactor to produce more power per unit volume, it must be designed for a high beta. That is, the plasma pressure (density times temperature) must be the highest possible for a given magnetic field strength without disrupting the plasma confined by that field. At the Impurity Study Experiment (ISX-B), where members of the Fusion Energy Division are experimenting with high-beta plasmas, plasma pressure is raised by injection of neutral beams for heating the plasma and by sophisticated fueling techniques for increasing the density. Both the neutral beam injection and the fueling techniques were pioneered at Oak Ridge. The fueling techniques, involving the high-speed injection of tiny pellets of frozen hydrogen into the tokamak plasma, are showing promising results in ISX-B and will soon be applied to the Poloidal Divertor Experiment (PDX) at Princeton, New Jersey. The PDX is a device that tests the use of special magnetic field coils to divert plasma impurities to a collection chamber to prevent impurity-induced destruction of the plasma.

In tokamaks, the density of startup plasmas is typically low and falls as plasma particles escape to the wall, thus requiring refueling to maintain or increase plasma density. In many experimental fusion devices, refueling has been done by introducing puffs of hydrogen gas. However, this method does not work so well in larger ones because the new fuel is not propelled fast enough to penetrate to the center of the plasma. Gas puffing is particularly ineffective in divertors like PDX because the new gas tends to stop at the plasma surface and hence is likely to be diverted along with impurities.

To overcome these problems, Stan Milora and Chris Foster have devised a gunlike pneumatic injector that propels fuel pellets about the size of a BB sufficiently fast to penetrate to the plasma center and significantly increase plasma density. Operating on the principle of a miniature air rifle, this device uses pressurized helium to blast a single pellet of hydrogen into the ISX deuterium-hydrogen plasma. Injection of a 1-mm hydrogen pellet with this device resulted in a fivefold increase in density of an ISX plasma. Milora attributes the success of this experiment to the pellet size, the ability of neutral beams to stop the pellet at the plasma center, and the velocity of the injected pellet. The velocity performance of the pellet injector has now been increased from 350 to 1000 m/sec.

In four years, the pellet injection program has come a long way. In the first test of this concept, small hydrogen pellets containing less than 1% of the total plasma-particle content were injected into ORMAK at speeds of 100 m/sec. Because of their small size, these pellets penetrated no farther than 6 cm into the 25-cm plasma column, and no detectable increase in plasma density was observed. The small size was used because theorists believed that the plasma would be significantly perturbed if the injected pellet contained more than 1% of the total plasma content. In early 1978, the first successful demonstration of pellet refueling was achieved on ISX-A, when the plasma density was increased 35%. Early in 1979, a 500% increase in plasma density was demonstrated by using larger pellets with no adverse effect on the plasma's stability. Use of the pneumatic pellet injector on the PDX is expected to increase plasma density by 40 to 50%.

Another device developed for pellet injection is the mechanical pellet accelerator, a prototype of which has been operated at a pellet velocity of 300 m/sec and a delivery rate of 150 pellets per second. Invented by Foster, the accelerator makes use of the centrifugal force of a rotating arm which slices off pellets from extruded frozen hydrogen (like a razor blade chopping off pieces of toothpaste squeezed from the tube) and accelerates them. This device will be tested this year on ISX.

C. E. Thomas has made photographs of the pellets using an intense ruby laser light source. In his shadow graphs, the pellets entering the plasma look like shortened beer cans and then become shaped like kidney beans as the hot plasma (15 million degrees or more) consumes the pellets originally frozen at −263°C. These photographs are used to study pellet ablation in superhot plasmas. By using high-speed camera techniques, the researchers can determine how fast the pellet disappears and how far it penetrates the plasma. This information helps researchers determine what changes are required in pellet size, injection velocity, neutral beam power, and the plasma itself to maximize density increases without disturbing the plasma equilibrium.

Pushing Up Beta in ISX-B

In tokamak fusion reactors, magnetic fields will be used to confine heavy hydrogen plasmas, the ionized gases that fuel these devices. To get maximum power from the plasma, the plasma must be very hot and dense so that there are enough fusion reactions to yield large quantities of heat. However, if the product of the plasma temperature and density (plasma pressure) is too high for a given magnetic field, the plasma may become unstable and lose its energy to the tokamak wall.

This electron micrograph of a stainless steel single crystal under stress shows a crack propagating from right to left and a plastic zone where dislocations occurred. The plastic zone shows an inverse pileup of dislocations, the number of which corresponds approximately to the crack opening displacement. This observation at ORNL is the first direct experimental evidence for an important dislocation theory of fracture.

Because the electricity used to generate large magnetic fields for tokamàks is costly, it is imperative that these fields be used at top efficiency. This is done by raising plasma pressure to the maximum limit possible without disrupting the plasma—but what is this upper limit, and how can it be achieved so that more economical fusion reactors can be designed?

To help answer this question, ORNL researchers in the Fusion Energy Division are testing how efficiently the 12-kG tokamak magnetic field on the Impurity Study Experiment (ISX-B) can contain a high-pressure plasma. A measure of this efficiency is termed "beta"—the ratio of plasma pressure to magnetic pressure exerted by the tokamak field. The plasma pressure may also be construed as a measure of the fusion power produced, whereas the magnetic pressure is a measure of the power usage and cost. The higher the value of beta, the more economical a fusion reactor will be.

It is generally accepted that commercial tokamak devices will require a beta in the range of 5 to 10% to produce power economically. In contrast, ORNL's first experimental tokamak (ORMAK) achieved a beta of less than 1%. ORNL theorists have calculated that ISX-B can attain a beta of 6 to 10% with a circular or D-shaped plasma.

Using 1 MW of neutral beam power from injectors developed at ORNL, ISX-B has achieved a beta of up to 3%. The peak temperatures attained by neutral beam heating of plasma are in the range of 15 to 17 million degrees, and the density is typically 5×10^{13} particles per cubic centimenter.

By increasing neutral beam power and by changing the shape of the plasma, ISX-B researchers hope to achieve even higher betas in the next two years. The maximum capability of the current neutral beam system is 1.8 MW, which is expected to be applied this year. In 1980, the beam power will be raised to 3 MW.

Says John Sheffield, head of the Experimental Confinement Section: "The projected beta should reach the reactor-relevant regime, assuming no instabilities or other untoward effects. The ISX-B results are very encouraging for magnetic fusion, in that a key economic parameter has been raised to within 25 to 50% of the level needed for the production of economic fusion power."

Solid State, April 18–19

How Solids Crack

Recent studies at ORNL have shown that theory of fracture is only as good as it is "cracked up" to be. An understanding of fracture in solids is important because construction materials frequently crack under prolonged stress in energy production, transmission, and storage systems. Radiation, extreme temperatures, or harsh chemical environments (stress corrosion) may damage structural materials of vessel walls and pipes to the extent that they fail under stress and have to be repaired or replaced. Solid state physicists at ORNL are trying to understand the basic mechanism of fracture initiation and crack propagation in hopes of using this information to predict the stress required for fracture in structural materials.

ORNL physicists Mike Ohr, S. Kobayashi, S. Chang, and Jagdish Narayan have shed light on fracture mechanisms through their electron microscope studies of fracture in solids. These studies have provided the first direct experimental confirmation of an important theory of fracture proposed by a group of British scientists—B. A. Bilby, A. H. Cottrell, and K. H. Swinden. The so-called BCS theory predicts that planes of atoms in the crystal, in response to stress, may slip one or more atom spaces relative to other planes of atoms. These slippages, described as dislocations, give rise to plastic deformation in the crystal. Then as the atomic planes continue to slip, a crack occurs and begins to grow. The theory states that the extent of the crack opening should correspond quantitatively to the number of dislocations emitted from the crack tip.

Using a deformation holder designed and built by Tom Noggle, Ohr and his associates applied in-situ tensile deformation (pulling on opposite ends) to a thin foil specimen while observing it with a transmission electron microscope at a magnification of 100,000×. According to Ohr: "As the stress was applied to the crystal, a crack was initiated at the edge of the notch. The crack was made to propagate into the crystal by gradually increasing the stress. The most noticeable feature is the band ahead of the crack tip which has intense plastic activity. The extent of plastic activity can be measured in terms of the density of dislocations in this band. The dislocation density is extremely high near the crack tip and it decreases gradually away from the tip. The band, therefore, represents an 'inverse pile-up' of dislocations."

In their studies of stainless steel, a ductile metal, the physicists measured directly the crack opening displacement by counting the number of dislocations in the plastic zone. They found approximately 300 screw dislocations in the plastic zone which correspond to the crack opening displacement of 850 Å, in excellent agreement with the BCS theory. When they studied molybdenum (a semibrittle metal), they found that the total number of dislocations in the plastic zone approximately accounts for the crack opening displacement. However, their studies of a brittle ceramic material—magnesium oxide—indicated that there was an insufficient number of dislocations in the plastic zone to account for the crack opening. The low observed dislocation densities in magnesium oxide indicate that plastic deformation does not relieve the stress concentration at the crack tip.

Ohr and his associates concluded that the ductile-brittle nature of a material is determined by the extent of plastic deformation that can be accommodated at the crack tip. Thus, studies of the microscopic phenomena that occur when a crack is in progress give some indication as to how a given material will respond to stress.

Energy, April 23–24

Since its establishment in 1974, the Energy Division has grown from 58 to 106 professional employees and has made numerous contributions of analytical information useful to energy policymakers in Washington. According to Bill Fulkerson, director, the division has contributed importantly to developing a strong nonnuclear program at ORNL as well as assessment capabilities and has spawned a major energy conservation program at the Laboratory. Work on environmental assessments has been broadened to include not only the impacts of nuclear power plants but also of fossil, geothermal, and solar facilities. The division has developed energy demand models to help policymakers understand the potential effects of projected policy and technological changes on fuel use both by the United States as a whole and by regions. Achievements of the division have made social science acceptable as a viable Laboratory discipline.

Aesthetic Impacts and Nuclear Power

For the first time in its history of preparing environmental impact statements, ORNL has recommended the denial of a construction permit for a proposed nuclear power plant. The Nuclear Regulatory Commission has endorsed this recommendation. The primary objection to the proposed plant site in Greene County, New York, lies in aesthetic grounds. Carl Petrich, landscape architect, has been instrumental in demonstrating the adverse aesthetic impact that would likely result from the construction of the power plant. The engineering designs called for a 137-m cooling tower to minimize thermal and mechanical impacts on aquatic life in the Hudson River. The proposed site at the foot of the Catskill Mountains is in the vicinity of Olana, an artist's mansion that is considered a symbol of the 19th century romantic period, much as Thomas Jefferson's Monticello is deemed a symbol of the 18th century federalist period. A national historic landmark, the Persian-style mansion was built by Frederic Edwin Church, a member of the Hudson River School of painters and the artist who helped establish landscape painting as America's first and highest art form in the 19th century. The landscape paintings of the school, many of which are as detailed as photographs, underscore the romantic period's theme that man and industry can coexist with nature.

However, Petrich has determined from a visual preference survey of residents of this Hudson River region that man there is not so willing to coexist with a natural-draft cooling tower that would emit a visible plume. The survey showed that the New Yorkers who would view such a cooling tower value scenic quality as well as cultural and historical resources and reject the idea of having a power plant and cooling tower dominate the landscape. In Petrich's judgment, a cooling tower and plume in this pastoral region would be viewed as a symbolic as well as physical intrusion of 20th century technology into a rare 19th century setting. To the region's residents and tourists as well as to artists and art historians throughout the country, tower and plume would be an intolerable incongruity.

Water Heating by Heat Pumps

Water heating consumes 15% of the energy used in the residential sector. Most electric water heaters use resistance heating elements, so an opportunity exists for improving energy efficiency in this type of appliance. Virgil Haynes of the Energy Division is managing a Department of Energy program that focuses on development of high-efficiency appliances, including water heaters. (A recent development in this program was a refrigerator-freezer that consumes 30% less energy than the best conventional units.) Under this program, two subcontractors—Energy Utilization Systems and Foster Miller Associates—are developing heat-pump water heaters. Preliminary estimates indicate that these water heaters (one type is Rankine cycle, and the other is Brayton cycle) will use 40 to 50% less energy than conventional resistance-type heaters but will cost about $300 more. However, money saved in operating costs can offset the difference in capital cost in 2 to 2.7 years—a reasonable payback period (for Kansas City electric rates).

How do the economics of a heat-pump water heater compare with that of solar water heating? Energy Division's Dennis O'Neal has studied this very question. It has been projected that the potential national energy savings for heat-pump water heaters is larger than that for solar water heating. The economics to the homeowners are more favorable for heat-pump water heaters than for solar water heaters with federal tax credits. He also found that the household energy benefits of heat-pump water heaters would be greatest for New England, the South, and the Northwest. Although uncertainties exist in capital costs and performance of both types of water heaters, O'Neal concludes that these systems offer economical alternatives to conventional resistance-type water heaters. Moreover, the economics and popularity of these newer systems should improve as the cost of electricity rises.

Underground Buildings for Energy Conservation

An energy analysis performed by Randy Barnes indicates that a considerable reduction in energy used to heat and cool building space can be attained by constructing the building underground and incorporating direct-gain space heating. Because the earth has a lower seasonal temperature fluctuation and thus offers insulation against the vicissitudes of above-ground climate, a fairly constant, confortable temperature can be maintained in earth-covered structures.

Earth shelters also have other advantages. They offer additional privacy, blend in with the landscape, and could serve as disaster shelters, suggesting that homeowners might be allowed to pay lower insurance premiums. In addition, the psychological barrier of seeming to be isolated from the outside world's scenery and sunshine can be overcome by designing the shelter with a skylight and a view from the south side of the outdoors.

Barnes and Hanna Shapira, architect, working under the leadership of Connie Chester, have performed design studies of earth-covered buildings complete with skylights, extended canopies to keep out the summer sun, and reflecting-insulating window blinds. Says Barnes: "An underground building which utilizes the south-facing windows as well as the structural mass to collect and store solar energy could save approximately two-thirds of the energy normally used for heating conventional above-ground homes."

Shapira has completed a design for an earth-covered structure for the proposed Joint Institute for Heavy-Ion Research, which would provide housing and office space for visiting scientists working at the Holifield Heavy-Ion Research Facility. The building will be instrumented to provide data for comparing systems and validating computer analysis and design codes.

For future designs of other underground buildings, Shapira and Barnes feel that an economic study is needed to show whether this type of structure would be compatible with conventional buildings on the market.

Environmental Sciences, May 9–10

The PETSUB Study

As part of the formulation of the second National Energy Plan (NEP-II), ORNL was asked to assess the environmental and social impacts of policy options being considered by the Department of Energy (DOE). Marti Salk reported on several assessments in which environmental analyses were especially important.

In this project, DOE provided information to ORNL about possible policy initiatives as it became available. Using information and expertise on hand in the Oak Ridge area, an interdisciplinary research team under the leadership of Tom Wilbanks of the Energy Division developed draft assessments. These were reviewed by ORNL staff, revised as appropriate, and submitted to the DOE Office of Policy and Evaluation. Responding rapidly, the team performed both quantitative and qualitative analyses, integrating and condensing the results into a concise report focused on major conclusions.

Ten such reports were prepared, and a variety of other technical support was provided to DOE. Of these, the assessments of a possible Petroleum Substitutes Incentive Program (PETSUB), an oil shale tax credit, and incentives for alcohol fuel production and use (including gasohol) were discussed by Salk.

PETSUB was a policy option that would mandate purchases of synthetic liquid fuels by refiners and other users of petroleum in order to ensure a market for synfuels. For this, the team assessed the impacts of the development of oil shale, coal liquefaction, methanol from coal, and ethanol from biomass. The assessment concluded that state and federal air quality standards are likely to limit shale oil production based on currently available technologies and that a variety of significant uncertainties remain about the environmental and health consequences of synfuel production and use. As a result, it might be difficult to achieve the supply levels that would be required to keep purchasers from violating the law.

In line with this assessment, NEP-II did not include PETSUB. Instead, it proposed an oil shale tax credit, coal liquefaction demonstrations, and increased support for coal research, development, and demonstration, thus placing the emphasis on reducing supply uncertainties rather than specifying utilization targets at this time.

Such assessments are clear examples of the contribution a technical research team can make to the policymaking process at the national level. Although the time schedule limits the amount of original research that can be done, the assessments offer an important way for the country to utilize what ORNL has learned from many of its energy and environmental research programs.

Engineering Technology, June 7-8, 1979

Risks of Energy Sources

Of all the U.S. energy sources, the risk to workers and the general public is lowest for the natural gas and nuclear industries, and the risk of death or injury is highest for the coal industry, including synthetic fuel production.

These conclusions were derived from occupational injury and accident data developed by ORNL's Engineering Technology Division as input to the Strategic Environmental Assessment System (SEAS), a set of 29 interrelated computer programs used to provide forecasts in a number of areas. Originally written by the University of Maryland and the Environmental Protection Agency for economic policy studies, SEAS has been expanded to cover U.S. energy flow, environmental impacts, pollutants, and occupational and public risks of various conventional and unconventional energy sources.

In preparing the occupational risk data for the Department of Energy's Division of Environmental Impacts, Harry Hoy and his associates used these basic data sources: Mine Safety and Health Administration, Occupational Safety and Health Administration, Bureau of Labor Statistics, National Safety Council, Department of Transportation, and Railway Transportation Administration. They gathered and converted the data to show the rate of occupational injuries for each 10^{12} Btu of energy produced by mining, processing, transportation, storage, operation and maintenance, waste disposal, and construction.

The data are presented in terms of lost days of work per 10^{12} Btu. The units nationally agreed upon are 6000 man-days lost for each fatality or permanent disability, with a lesser number of days for each loss of arm, hand, eye, ear, total sight, or total hearing.

The number of lost days per 10^{12} Btu for each conventional energy source is 30 for natural gas, 32 for nuclear, 57 for oil, 160 for hydroelectricity (largely due to dam construction accidents), and 310 for coal (mostly due to mining accidents). For nonconventional energy sources, equivalent lost days are 36 for geothermal, 83 for wind, 94 for solar, 267 for methanol, and 323 for synthetic fuels.

The ORNL figures are lower than those for occupational risk provided by the controversial report written by Herbert Inhaber (scientific advisor to Canada's Atomic Energy Control Board who discussed his report at ORNL on August 3), but the comparative risks of the energy sources are about the same. Based on the Inhaber report, the combined public and occupational risks for selected energy sources are calculated to be highest for coal, oil, methanol, and solar, and an order of magnitude lower for natural gas and nuclear energy.

Analytical Chemistry, June 18–19

Time-of-Flight Spectrometry

The rapid growth of the communications industry in the past decade has resulted in the development of many innovative technologies for handling the burgeoning needs. One technology that has evolved, fiber optics, is the development of modified quartz strands to replace the costly and diminishing copper traditionally used to transmit signals. Knowing that the speed of light in a material like quartz depends on the wavelength, Harley Ross conceived the idea of separating a pulse of light through a very long optical fiber into a measurable spectrum at the other end. It was the new fiber optic technology that turned this concept into reality. The new type of spectrometer uses a single detector, has no moving parts, and has a built-in capability for measuring spectra as a function of time.

Bill Whitten reported on his and Ross's feasibility experimentation, performed on a Corning optical fiber 1100 m long and $125\,\mu$ in diameter, less than the thickness of two human hairs. The extreme length of the fiber is necessary to separate the photons of different wavelengths, and even with a fiber over a kilometer in length, the time of flight must be measured in nanoseconds to get accurate spectra.

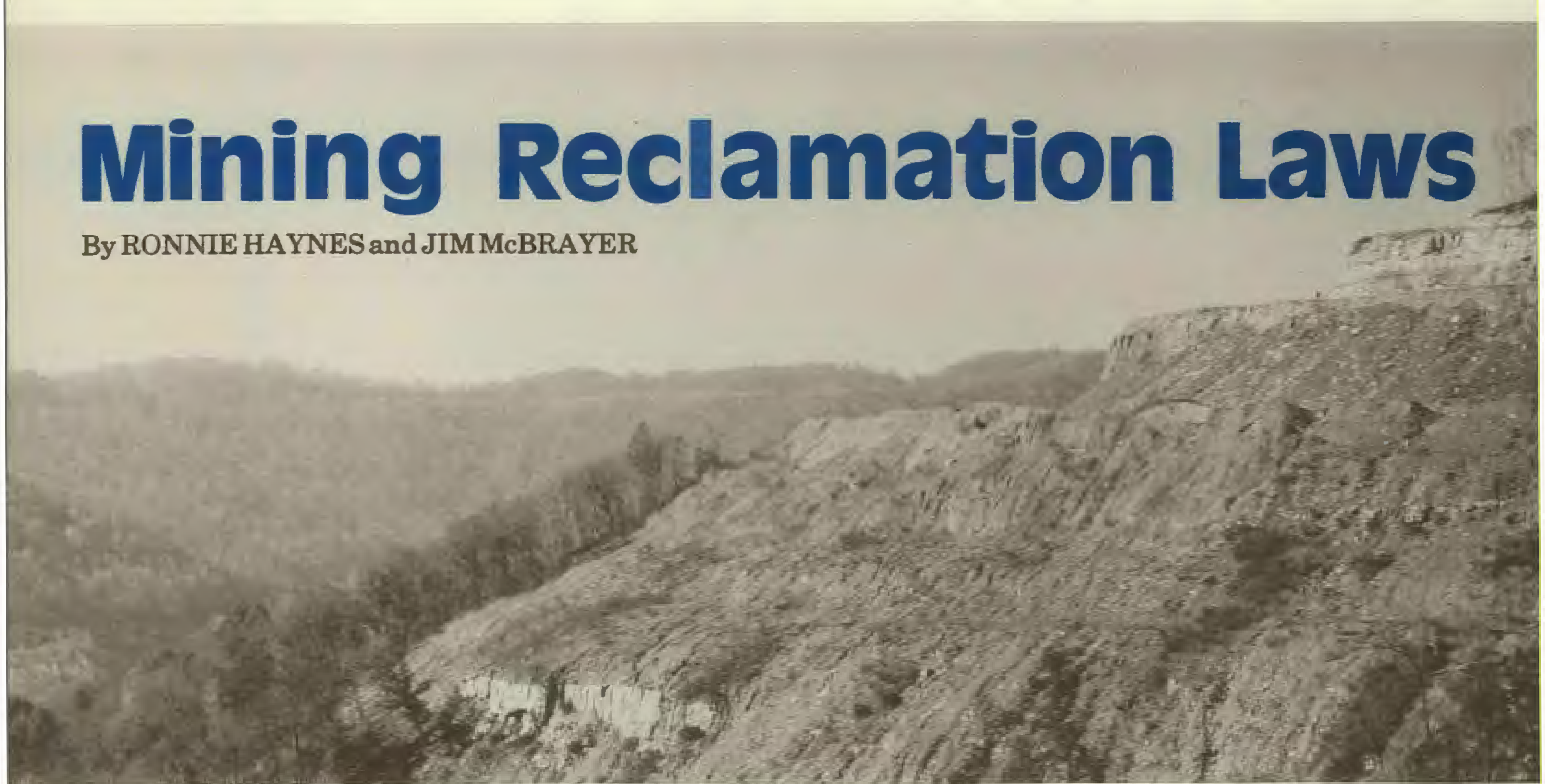
Using a weak light pulse of very short duration, they were able to determine the wavelengths of the photons from their transit time. The instrument performs these measurements repeatedly and combines the results to produce an optical spectrum. These preliminary studies have shown that fibers available today are of sufficient quality to produce a practical spectrometer.

The next generation time-of-flight spectrometer, now in the planning stage, will use a very intense, subnanosecond light source and advanced electronic instrumentation that will permit the experimenters to generate a complete spectrum with each flash of the source. The combination of very short time resolution and rapid data acquisition will be useful for studying spectra that change rapidly. Applications are expected in combustion studies, photochemical reactions, and plasma diagnostics, among others. ornl

Groundbreaking for the Joint Institute for Heavy Ion Research took place July 10 on a cloudy day. Official groundbreakers were, from left, Alex Zucker, ORNL associate director for physical sciences; Herman Postma, ORNL director; Alexander Heard, chancellor, Vanderbilt University; Jack E. Reese, chancellor, University of Tennessee-Knoxville; Roger F. Hibbs, president, Nuclear Division; and James E. Leiss, associate director for high energy and nuclear physics, Office of Energy Research, DOE. The earth-sheltered facility, designed by staff architect Hanna Shapira with technical input from Paul R. Barnes, will have many energy conservation features. The building will provide temporary accommodations and office space for visiting scientists using the new accelerator in the nearby Holified Heavy Ion Tower.

Mining Reclamation Laws

By RONNIE HAYNES and JIM McBRAYER



ORNL lies along the edge of the southern Appalachian coal field, as is apparent to anyone driving north into Oak Ridge. On a clear day, the benches and highwalls of surface mines give an angular outline to the Cumberland Mountains to the northwest, a vista more in keeping with the mountains of New Mexico than with eastern Tennessee. The visual impact of steep-slope surface mines, not to mention general concern for severe soil erosion and stream sedimentation, influenced public support for comprehensive land reclamation legislation now in effect following enactment of the *Surface Mining Control and Reclamation Act of 1977* (Public Law 95–87) and the subsequent permanent regulatory program [*Federal Register*. (Mar. 13, 1979)]. This significant legislation contains numerous controversial provisions, including a requirement for elimination of highwalls, return of affected lands to their approximate original contour, and other specific requirements for mining on steep slopes. These and many other important issues are part of the complex and currently evolving history of surface-mining regulations in Tennessee and in the nation.

Tennessee

Tennessee did not enact surface-mining regulations until 1967. Although the 1967 act was weak in environmental protection measures, it did create the Division of Surface Mining within the Department of Conservation. The original act was strengthened by amendments in 1972, 1974, and 1976. The 1976 act was generally considered to be one of the stronger environmental protection laws in the Appalachian region, but, among other things, it still did not provide for elimination of all highwalls. It also permitted some dumping of spoil materials downslope. In addition, opponents of surface mining in Tennessee lacked confidence in the state's ability to implement and enforce the regulations successfully.

Since the 1940s, the Tennessee Valley Authority (TVA) has financially supported numerous reclamation demonstration projects and has established itself as one of the leaders in reclamation research in the southern Appalachians. TVA was also active in its support of the newly enacted *Surface Mining Control and Reclamation Act of 1977*. Besides the state requirements, TVA has required, since 1965, reclamation of all land involved in their coal-purchase contracts. Following enactment of Public Law 95–87, TVA modified the reclamation provisions of its coal-purchase contracts and now

Ronnie Haynes recently joined the U.S. Fish and Wildlife Service where he is Region IV Activities Leader for Coal and Minerals. While a research associate in the Environmental Sciences Division, he contributed to environmental assessments of coal mining in Alabama, landfills, pipeline gas, enhanced oil recovery, and uranium mines and mills. He received his Ph.D. in zoology from Southern Illinois University in 1976. Jim McBrayer is a research associate in the Environmental Sciences Division where he has contributed to environmental assessments of coal and lignite mining, aquifer thermal storage, enhanced oil recovery, uranium mines and mills, and nuclear power plants. He received his Ph.D. in ecology from the University of Tennessee in 1973.

requires compliance with all mining and reclamation provisions of that law and subsequent federal and state regulations. TVA has also recently established a program to assist small, independent operators in complying with federal and state mining regulations.

Federal Action

The enactment of Public Law 95-87, after six years of congressional activity and three presidential vetoes, has begun a new era in coal mining and in environmental protection. The act and the permanent regulatory program have provided a minimum set of environmental performance standards; provided a mechanism for funding the program; established criteria for reclaiming the nation's previously affected abandoned mine lands; defined procedures for public participation, review, and approval of mining permit applications; and created the new Office of Surface Mining Reclamation and Enforcement (OSM) within the U.S. Department of the Interior to implement the act. OSM will delegate primary jurisdiction to states having approved programs and oversee the activities. With some major exceptions, state programs are to be approved by OSM no later than June 3, 1980.

Some of the important issues in southern Appalachia that are covered by the act include special requirements for steep-slope mining, mountaintop removal, disposal of acid-producing materials and prevention of water pollution, reclamation of abandoned mine lands, and designation of lands as unsuitable for all or certain types of coal mining. These issues are defined and discussed at length in the permanent regulations for issuance of new mine permits [*Federal Register* (Mar. 13, 1979)] and management of abandoned mine lands [*Federal Register* (Sept. 28 and Oct. 25, 1978)].

Steep-Slope Mining

Both the new act and the permanent regulations define special environmental standards for mining operations on steep slopes, defined as slopes above 20°, or lesser slopes as designated by the regulatory authority, either federal or state. These performance standards include eliminating deposits of spoil materials on the downslope; return of disturbed sites to approximate original contour, including elimination of highwalls; and restrictions dealing with disturbance of land above the highwall, disposal of excess materials, and construction of drainage channels. Variances may be granted by the regulatory authority if certain, specific criteria are met.

Mountaintop Removal

Mountaintop removal is a method of mining that transforms a mountaintop into a level or gently rolling land area. A variance allow-

According to a Soil Conservation Service report (Status of Land Disturbed by Surface Mining in the U.S. as of July 1, 1977 by States), Tennessee may exhibit as much as 33,000 acres of abandoned coal mine lands. These lands are in varied stages of revegetation, mostly as a result of natural plant succession. Plans for reclaiming these lands are to be developed according to the criteria and programs established through P.L. 95-87.

ing for this method of mining may be granted by the regulatory authority if the proposed operation and reclamation are part of an approved alternate land-use plan and all other applicable performance standards, other than those requiring return to approximate original contour, are met.

Protection of Waters

Surface mining and the surface effects of underground mining in Appalachia are well known for their deleterious effects on waters and aquatic biota as a result of excessive erosion, sedimentation, and acid-mine drainage. Numerous portions of Public Law 95–87 and subsequent regulations demand the implementation of whatever state-of-the-art measures may be necessary to prevent acid-mine drainage and minimize or prevent other disturbances that could result in adverse changes in both surface and underground waters. These include specific procedures and requirements for design and construction of sediment ponds and haulage roads, disposal of acid-forming materials, and revegetation requirements.

Abandoned Mine Lands

Abandoned mine lands are defined as unreclaimed coal-mine lands that existed prior to August 1977 and were mined before there was a legal requirement for reclamation. Such lands are estimated at about 753,000 acres (1200 sq mi) in Appalachia. Reclamation programs will be financed by taxes of 35¢/ton on surface-mined coal, 15¢/ton on underground-mined coal, and 10¢/ton on lignite. Half of the monies will go directly to the state or Indian reclamation programs, while the remainder will be used to administer the program, help farmers restore affected lands, and provide technical aid to small operators. The initial thrust will be to correct "imminent threats" to the public health, safety, and general welfare. Subsequent efforts will be directed toward the reclamation of "lower priority" sites.

Lands Unsuitable for Mining

Regarding future constraints to coal extraction, possibly the most powerful part of Public Law 95–87 is Section 522, which establishes a program for the designation of areas as unsuitable for all or certain types of coal mining. With some important exceptions, Section 522 identifies areas where coal extraction is to be prohibited, such as national recreation areas, monuments and parks, trails, wildlife refuges, wilderness areas, and wild and scenic rivers. Other less-definitive criteria that may preclude mining, depending on interpretation by the regulatory authority, include areas where the proposed mining would (1) be incompatible with existing state or local land-use plans or programs; (2) result in significant damage to important historic, cultural, ecologic, scientific, or esthetic values or natural systems; (3) result in a substantial loss or reduction of long-range productivity of water supply or of food or fiber products; or (4) substantially endanger life and property through negative impacts to natural-hazard lands. Furthermore, a state regulatory authority may establish more stringent criteria for determining whether lands under its jurisdiction should be designated as unsuitable for surface-mining operations. Each state regulatory authority is also charged to establish a data base, an inventory system, and a petition process to designate non-federal and non-Indian lands of the state as unsuitable for all or certain types of mining. The impact of

Tom Zarger (TVA staff forester) points out a method of overburden handling while other participants walk down into the active pit for a closer inspection. The Federal Surface Mining Control and Reclamation Act of 1977 requires that this area be returned to its approximate original contour with the highwall eliminated.

implementing Section 522 on future coal extraction in Appalachia remains to be seen, but much will depend on the interpretation of environmental acceptability and significance of potential impacts by the regulatory authority.

Reclamation Research Council at ORNL

The present state of flux created by Public Law 95-87 was among the topics discussed when ORNL's Environmental Sciences Division and TVA's Division of Forestry, Fisheries, and Wildlife Development hosted a two-day meeting of the American Council for Reclamation Research last fall. The council was founded in 1973 as the Council for Surface Mining and Reclamation Research in Appalachia as a means of promoting, assisting, and supporting relevant research, educational programs, and other studies relating to land reclamation through effective communication among research scientists, regulatory agencies, landowners, and the mining industry. Membership is open to any person, agency, institution, or organization that subscribes to the objectives and policy of the council. Recent activities have included participation in discussions concerning the formation of an international reclamation association, development of a program for accreditation of technical schools offering training assistance in mining and land reclamation, and an offer of technical assistance to OSM.

The ORNL/TVA-sponsored meeting, the theme of which was "Reclamation Research in Tennessee," focused on current research activities in Appalachia and recognition of other research and assessment needs as related to the past and present history of surface-mining legislation in Tennessee and the nation.

The first day of the meeting was held in ORNL's D. J. Nelson Auditorium. Organized by Jim McBrayer, the program featured speakers from TVA's sponsoring division, The University of Tennessee, the U.S. Forest Service, and ORNL's Environmental Sciences Division. Topics included new revegetation systems for southern Appalachian surface mines, water quality changes associated with surface mining in Tennessee, and the reclamation of abandoned mine lands.

Field Trip

The second day was highlighted by a field trip to several coal mines in Campbell County in the nearby Cumberlands. The tour, organized by Tom Zarger of TVA, was designed to emphasize current mining and reclamation procedures and their effectiveness in minimizing or preventing environmental impacts addressed by Public Law 95-87. Although most of the sites visited were mined and reclaimed prior to enactment of the law, they also demonstrated several TVA-supported projects of reclamation methods that are now included in the federal act. Thus, the group visited a diversity of sites that included examples of revegetation approaches, back-to-contour reclamation, mountaintop removal, haulback and controlled placement mining, augur mining, and abandoned mine lands.

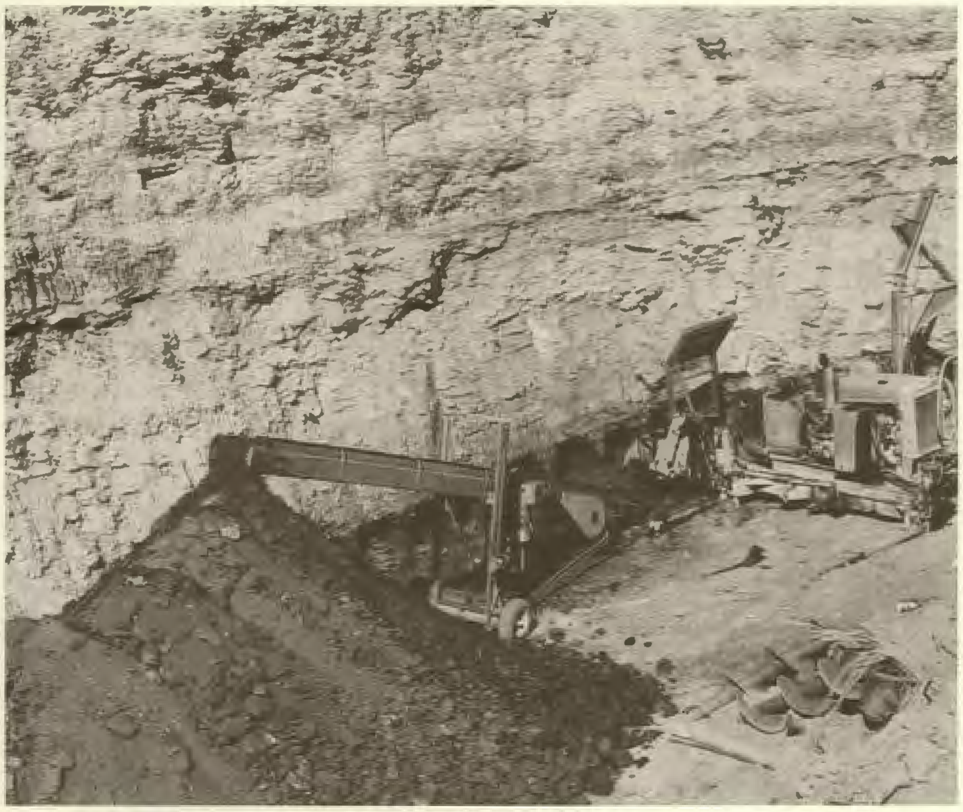
The casual atmosphere of the tour promoted a steady exchange of thoughts and ideas among the participants. Concern, for instance, was frequently voiced for the cost versus the value of topsoil-

Abandoned and deteriorating mine roads contribute to erosion and sedimentation and restrict access to abandoned mine sites.

ing: replacement of the "A soil horizon" (the uppermost layer of the three major soil horizons) and return to original contour on the rather infertile soils and steep slopes of Appalachia. Misgivings were also expressed regarding the potential impact of designating lands as unsuitable for mining of recoverable coal reserves. Research and assessment needs that were identified included:

1. the lack of data for refining environmental performance requirements, especially regarding site requirements and adaptability of native vegetation;
2. a need to study the effects of storage of topsoil and other soil materials on their physical, chemical, and biotic properties;
3. the need for information regarding the evaluation of methods of application of topsoil and other overburden materials used to achieve optimum plant productivity;
4. a need to understand the impacts of these measures on groundwater hydrology;
5. the need to develop ecologically sound land-use plans for abandoned mine lands, many of which have become revegetated through years of natural plant succession.

In addition, it was recognized that a much more useful system for transferring technical information and descriptive data should be developed and made available to users. Some of these thoughts will or have become part of the many research and assessment projects now being proposed for study.



Auger mining is the mining of coal at a cliff or highwall (as shown here) by drilling holes laterally into an exposed coal seam and transporting the coal along an auger bit to the surface. Public Law 95-87 sets forth special performance standards for auger mining.

Need for More R&D

ORNL has not previously played a significant role in coal-mined land reclamation research. Most of this work in southern Appalachia has been conducted by TVA, the U.S. Forest Service, and universities. The Environmental Sciences and Energy Divisions have produced their National Coal Utilization Assessment, which examines the potential impacts of coal extraction in the South, and have collaborated in the preparation of several other coal-mining-related documents for the Department of Energy (DOE) dealing with the president's National Energy Plan. These divisions also provide technical assistance to DOE in coordinating research of coal extraction and reclamation issues, to the U.S. Department of Agriculture in their Rural Abandoned-Mine Land Program, and to the OSM. OSM has engaged the Energy Division, under a subcontract with the operator, to develop criteria and guidelines for, and implementation of, a national inventory system for abandoned-mine lands. This task also includes continuing analysis, maintenance, and updating of data sets. Future projects proposed to DOE include an analysis of such constraints on coal extraction in the South. These would include designation of land unsuitable for mining, evaluation of reclamation strategies on surface-mined land in Appalachia, and a reclamation tour and review of such mined lands.

Many varied research and assessment needs have arisen from the enactment of Public Law 95-87, providing challenging opportunities in this very exciting area of energy technology and environmental protection. It is time for the establishment of a viable research and assessment program that provides the type of information needed to assist coal operators as well as to assess and evaluate significant environmental impacts of coal extraction and reclamation.

Additional information about activities and membership in the American Council for Reclamation Research can be obtained from William T. Plass, chairman, American Council for Reclamation Research, U.S. Forest Service, P.O. Box 152, Princeton, West Virginia, 24740.

BOOKS

Economic and Environmental Impacts of a U.S. Nuclear Moratorium, 1985-2000, *by Charles E. Whittle, coordinator of study team at the Institute for Energy Analysis. MIT Press, Cambridge (1979), 381 pages, $17.50. Reviewed by James Dick, economist in ORNL's Energy Division.*

Recent events have clearly pointed out the possibility that nuclear power may play a much smaller role in future energy production in the United States than was previously expected. The implications of this possibility are analyzed in some detail in *Economic and Environmental Impacts of a U.S. Nuclear Moratorium, 1985–2000.* The premise of this study is a moratorium on the contribution of nuclear power to the U.S. energy supply. Analyses and results are developed for alternative energy supplies with and without the nuclear moratorium.

The economic analysis focuses on the future cost of electricity, depending on the generation mode (nuclear or coal), the level of future demand, and the cost variables, and includes various rates of capital charges and combinations of price increases for uranium and coal. The results point to cost savings that favor the nuclear technology over coal, but the advantage in all cases is less than 1% of the cumulative gross national product (GNP) for the period of comparison. The regional impacts vary with the relative cost of coal. In the case of a moratorium, the area affected most would be New England, where coal is relatively expensive. The northern Rocky Mountains and the Great Plains, which have abundant low-cost coal supplies, would experience little if any electrical cost increases.

The analysis of environmental implications of a moratorium depicts the trade-offs between the increased radiation hazards of nuclear power and the air pollution problems and mining accident risks associated with the coal alternative. Plutonium proliferation, climatic changes, and land-use impacts associated with the nuclear and coal alternatives are also discussed. Several criteria indicate a modest increase in air pollution if coal is used in lieu of nuclear power for expanding generation requirements. However, the analysis also indicates that, compared with existing emission levels, scrubbers on utility boilers and expected improvements in automotive emissions would result in lower total emissions (excepting particulates) in the year 2000 even if there is a nuclear moratorium.

In addition to the detailed analysis of fossil-nuclear options, the study provides a brief but interesting discussion of alternative long-range energy supplies. Some general observations are made about the implications of the high-energy nuclear society and the lower-energy solar alternative, and the general nature of the trade-offs for the alternative scenarios is described. The brief discussion on the issue of social values that might be traded off between nuclear and solar futures indicates that there are important differences in life-style between these future alternative energy scenarios.

Finally, it should be mentioned that an initial concern, and a stated objective of the undertaking, was to conduct a study that was not biased for or against nuclear energy. This objective seems to have been accomplished, because the overall approach is well balanced. In addition to being a source of information on many complex issues, the presentation avoids a strident advocacy, which is too common in the nuclear debate. Although there is bound to be disagreement on specific points, this book should sharpen our overall perspective of the nuclear and nonnuclear options.

Handbook of Common Methods in Limnology, *by Owen T. Lind, The C. V. Mosby Co., St. Louis, Toronto, London, (1979). 2nd Edition. 199 pages, illus, softback, $11.95. Reviewed by Charles S. Shoup, formerly of the U.S. Atomic Energy Commission, Oak Ridge Operations.*

This book accomplishes its purpose in concisely presenting the principal standard methods used by the limnologist in studying streams, lakes, and ponds. It is especially addressed to the beginning aquatic biologist. The introduction contains guidance to the literature with admonitions and suggestions for the investigator. Physical limnological methods presented include mapping and morphometry as well as the usual measurement procedures for stream flow, turbidity, illumination, and temperature. Chemical limnological methods include collection, sample storage, use of sampling instruments, laboratory procedures, and laboratory and field methods. Methods are given for the determination of pH, free CO_2, alkalinity, hardness, calcium, magnesium, dissolved oxygen, phosphorus, nitrogen, silica, sulfate, conductance, and residues and volatile matter. A special attribute of this book is that the author repeatedly calls attention to sources of possible error based on his own experience and suggests ways of avoiding such errors. In connection with almost all the procedures, there is a list of apparatus, reagents and their preparation, and, where applicable, a discussion of calculations plus useful comments on safety.

There is particularly good coverage of the methods for collecting, separating, and counting plankton and benthic organisms, and identification references are given for the investigator. The book has two appendices: one provides useful conversion factors and the other lists names and addresses of sources of limnological apparatus and supplies. There is a concluding list of major references plus an index. This book gathers into a handy volume much method information that otherwise would need to be collected from a variety of sources, but beyond this time and energy savings, the methods presented are those known to be reliable and within the capabilities of the student investigator in the laboratory or in the field. The physical size of the book is such that it could probably be easily carried in a field kit. The author has been a member of the faculty in biological and environmental sciences at Baylor University since 1966.

Domenic Canonico, a metallurgical engineer, is the group leader of the pressure vessel technology laboratory in the Metals and Ceramics Division. His degrees (B.S., M.S., and Ph.D.) come from the Michigan College of Mining and Technology and Lehigh University. He is a fellow of the American Society of Metals, the 1978 recipient of the Rene D. Wasserman Award of the American Welding Society, and a member of Sigma Xi. His many years of service to the ASME Code—currently as chairman of the Subgroup on Strength-Steel and High-Temperature Alloys and as a member of the Subcommittee on Properties of Metals—beautifully qualify him to delineate, as he does here, the history of the Code, the contributions the Code has made to pressure vessel safety, and the contributions Oak Ridge National Laboratory has made to the Code.

PRESSURE VESSEL SAFETY

The Story of the ASME CODE

By DOMENIC CANONICO

The continued safe operation of many processing systems is dependent on the reliability of a pressure vessel. The definition of a pressure vessel in the *Chemical Engineer's Handbook* is acceptable for most vessels of interest to chemical engineers. The definition is as follows:

"A pressure vessel is a closed container of limited length (in contrast to the indefinite length of piping). Its smallest dimension is considerably larger than the connecting pipe, and it is subject to pressures above 1 or 2 psi. It is distinguished from a boiler which, in most cases, is used to generate steam for use external to itself."

However, this definition does not cover a nuclear pressure vessel, which indeed is used to generate steam for use external to itself.

Large pressure vessels operating under the process environments of high pressure and high temperature that are present in many commercial systems are capable of extensive damage if they undergo unexpected catastrophic failure. For example, an ammonia vessel that was pressurized internally to 5000 psi at 50°F failed during hydrostatic testing in England in December 1965. This vessel, which weighed 164 tons, had an internal diameter of 67 in. and was nearly 60 ft long. It had been fabricated, by welding, of low-alloy, high-strength, 5⅞-in.-thick steel plate and contained enough stored energy during hydrostatic testing to hurl a 2-ton

Comparison of sizes of pressure vessels for comparable plants

Reactor type	BWR	PWR
Identification	Hartsville-1	Palo Verde-1
Net electrical output, MW	1205	1235
Coolant pressure, MPa (psi)	7.2 (1040)	15.3 (2250)
Cylinder wall thickness, mm (in.)	145 (5.7)	231 (9.1)
Inside diameter, m (in.)	6.045 (238)	4.623 (182)
Height, m (ft)	~22 (~73)	~15 (~48)

piece of steel 152 ft. Although no one was injured in the accident, the lethal nature of such a vessel failure is evident. The ammonia vessel, however, was small compared to those currently being fabricated for light-water nuclear reactor applications. These vessels weigh nearly 1000 tons and represent some of the largest pressure-containing components being built today.

The assessment of nuclear pressure vessel safety has for many years been the responsibility of the Heavy-Section Steel Technology (HSST) Program, directed by Grady Whitman in the ORNL Engineering Technology Division. The results from the HSST Program involving tests to failure with thick-walled (6-in.), intermediate-size vessels (39 in. in outside diameter and 115 in. tall) show that the materials from which nuclear pressure vessels are fabricated are capable of withstanding internal pressures nearly three times design pressure, even in the presence of sharp flaws up to 8 in. long by 3 in. deep. The catastrophic failure of a nuclear pressure vessel during service is considered an incredible accident, as successfully demonstrated during the recent incident at the Three Mile Island nuclear reactor site in Pennsylvania.

The dimensions of nuclear pressure vessels pale, however, when compared to those proposed for commercial coal gasification processes. A gasifier pressure vessel for a two-train, 500×10^9 Btu/day HYGAS commercial coal conversion plant is nearly 250 ft tall, varies in inside diameter from 25 to 31 ft, and weighs about twice as much as that for a boiling-water reactor (BWR) or a pressurized-water reactor (PWR). The nominal operating pressures in the HYGAS process are similar to those for a BWR, but the process temperature is considerably higher (1700°F vs 550°F). A great deal of energy will be stored in an operating pressure vessel the size of a commercial gasifier. A cursory calculation based on a nominal design pressure of 1300 psi, a temperature of 1700°F, and a gas composition of 25% H_2, 25% CH_4, 30% H_2O, 10% CO, and 10% CO_2, showed that the energy stored in the conceptual HYGAS gasifier is about 4.4×10^{10} ft-lb, which is equivalent to nearly 29,000 lb of TNT. The potential destruction in such a unit if the vessel were to rupture instantaneously is comparable to 58 conventional 1000-lb bombs. The instantaneous release of this much energy would literally destroy the entire coal conversion facility in which it operated and could hurl fragments of steel hundreds of feet. Needless to say, such a failure is considered intolerable, and owners and manufacturers alike strive to prevent its occurrence.

The energy stored in a pressure vessel the size of the gasifiers in the HYGAS process is indeed impressive. However, concern for the reliable operation of a pressure vessel need not be as remote from our everyday living as that of a large coal conversion facility. Most of us sleep next to or above a water heater, a small appliance that satisfies the handbook definition of a pressure vessel since the act of heating results in a pressure increase. Such equipment is common in our daily living and, for the most part, is essentially ignored as long as it continues to provide hot water. Nonetheless, a faulty water heater is dangerous; for example, a 30-gal heater at 90 psi will flash to steam at 331°F and release nearly 3.2×10^6 ft-lb of energy, which is equivalent to over 2 lb of TNT. Thus, water heater failures are not unheard of, as evidenced by the one that occurred in West Knoxville a few years back. The heater was located in the basement of a brick-veneer, ranch-style home. The explosion completely destroyed the house; it lifted the house off its foundation and completely stripped the bricks off the outside walls. The failure of any pressure vessel, whether it is a small water heater or a large commercial boiler or reaction vessel, is a newsworthy item. For example, during the preparation of this article, the front page of the June 8, 1979, Knoxville *News-Sentinel* displayed a photograph of a house in which a water heater had exploded. The news story stated that "every wall was damaged by the concussion."

Pressure vessel failures are infrequent, and catastrophic failures are rare. Credit for their reliable service can, for the most part, be attributed to the development and use of codes and standards in our country and abroad. The probability of a failure

These photographs show the H. B. Grover and Company Shoe Factory before and after it was leveled in 1905 by one of the worst boiler explosions in history. The Brockton, Massachusetts factory collapsed, and 58 people died.

in a conventional pressure vessel is about one in every 100,000 reactor-years of service. Nuclear pressure vessels are considerably more reliable; it has been suggested that the probability of a nuclear reactor pressure vessel failure is less than one in every 1,000,000 reactor-years of service.

Dangerous 19th Century

This excellent safety record did not always exist. In the period between 1816 and 1848, at least 233 steamboats used on American waterways exploded, resulting in the death of approximately 2560 persons plus nearly 2100 injuries. The most infamous of the maritime failures occurred on April 21, 1865, when a boiler exploded aboard the Mississippi River steamboat Sultana. The boat left New Orleans with a passenger list and crew of 200 and stopped at Vicksburg to take on 2000 federal soldiers who had been released from Confederate prison camps. Seven miles north of Memphis, a boiler exploded, setting fire to the boat, and in 20 min the boat had burned down to its waterline. Fifteen hundred lives were lost in this catastrophe.

Boiler explosions were common in the late 1800s and early 1900s. The Hartford Steam Boiler Inspection and Insurance Company reported 5042 such events in the United States in the period 1890 to 1904. From 1889 to 1903, about 1200 people were killed in 1600 boiler explosions. Probably the catastrophe that prompted the enactment of a legal code of rules for steam boiler construction was the boiler explosion in a shoe factory in Massachusetts. Fifty-eight were killed and perhaps as many as 117 were injured, although there are conflicting reports regarding the number of injuries.

In 1907, the Commonwealth of Massachusetts enacted the first set of steam boiler construction rules, which covered three pages. Other states and municipalities in which boiler explosions had occurred recognized the benefits to be derived from proper design, construction, installation, and inspection, and their governing bodies began to enact their own rules. In 1911, New York and Ohio enacted boiler laws similar to those in Massachusetts; New Jersey, Indiana, and Delaware enacted laws in 1913, 1915, and 1916 respectively; and by 1920, Pennsylvania, California, Michigan, Arkansas, Oklahoma, and Oregon had followed suit. These boiler laws had slightly different requirements, so their enactment worked a hardship on manufacturers who wanted to build standardized boilers.

The Code

To minimize these fabrication problems, the American Society for Mechanical Engineers (ASME) undertook the responsibility for developing rules that would be acceptable to the manufacturers, the users, and the states. In 1911, the ASME council announced the appointment of "a committee to formulate standard specifications for the construction of steam boilers and other pressure vessels and for their care in service." The first ASME code, issued in 1914, covered power and heating boilers. Other sections were added, and the committee broadened its scope and interest, thereby gaining the support needed for its growth. By 1937, nine sections had been

issued, covering procedures for all phases of fabrication, materials selection, maintenance, and inspection of pressure vessels. Keeping pace with advancing technology, new sections were issued and old ones revised. Nuclear components, nondestructive examination, concrete—and even plastic—vessels gave rise to additional sections, so that today the ASME code consists of 11 sections and 22 books. Thus the code has grown from three pages in 1914 to today's volumes, which occupy approximately 42 running inches of bookshelf space.

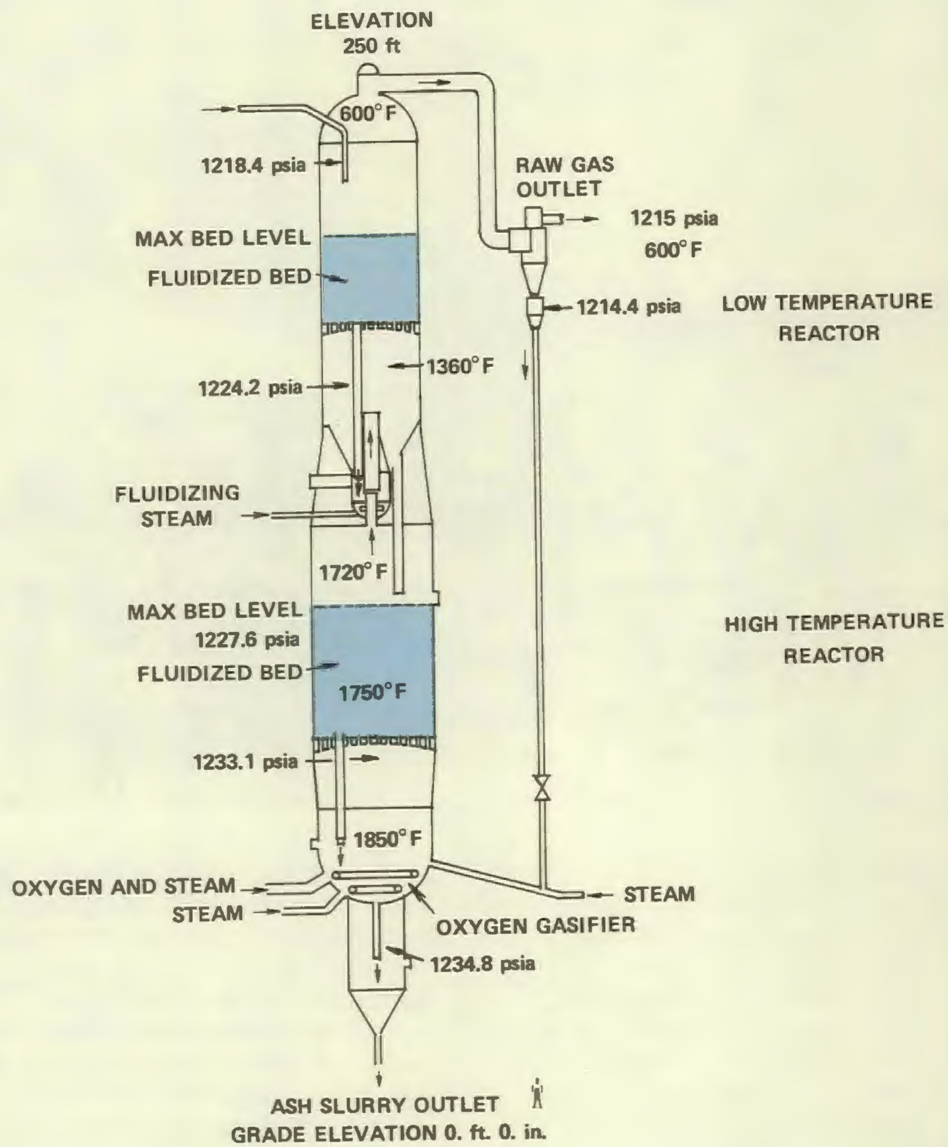
The ASME also publishes a book of code cases, a mechanism for interpreting and extending the code, and before the next edition of the code is printed (1980), six addenda will have been issued. These addenda, which comprise a winter and summer addendum for each of the three years preceding the new edition, permit users of the code to keep abreast of current actions that have become effective through approval of the main committee of the ASME code.

The main committee is composed of 30 members representing widely diverse backgrounds. Currently, the interest group representation is as follows: 8 manufacturers and 8 users of code equipment, 3 materials manufacturers, 2 insurance inspectors, and 3 regulatory representatives. In addition, 6 members represent general interest groups such as the Tennessee Valley Authority (TVA).

All actions incorporated into the ASME code are reviewed and accepted by the main committee before they become effective. The actions taken by this group, however, have previously been discussed, debated, and agreed upon through various working levels. Frequently, an action is initiated at a working-group level, usually a subgroup of a subcommittee, where it receives an in-depth review and where allowable stress values are assigned or other actions are taken. After the review is satisfied at the working level, an action is brought before the subcommittee from which that subgroup was assigned. There the action is again debated on a more general scale and, if acceptable to the subcommittee members, is forwarded to the main committee for approval. As many as 100 people may be involved in a single action. This constituency, with its diversity of backgrounds, interests, and experiences, provides checks and balances that are second to none.

Hundreds of individuals may be involved in a single section of the ASME code. For example, Section III, Nuclear Power Plant Components, has nearly 300 participants in its working group, subgroup, and subcommittee activities. These people are sponsored by their individual employers but do not specifically represent them. As individuals they contribute a great deal of their time to code activities. The main committee meets six times a year. Five of these meetings are held at the United Engineering Center in New York City and the sixth, held at a different place in the United States each year, is held jointly with the National Board of Boiler and Pressure Vessel Inspectors. Each of the five meetings is usually referred to as "Code Week," during which most of the subgroups and subcommittees also meet in New York.

A commercial coal gasification system based on the HYGAS process would use a gasifier pressure vessel more than 250 ft high. The vessel would be built in the coal field and would completely dwarf a six-foot-tall man as shown in this drawing to scale.



ORNL and the Code

Data incorporated into the ASME code are supplied by a number of organizations. In a talk given at a Nuclear Regulatory Commission seminar in Bethesda, Maryland, last year, Paul Brister, chairman of the main committee, specifically cited ORNL as a main contributor of invaluable information to the code. Indeed, it was the only national laboratory mentioned in his talk. In addition to providing data for the code, ORNL supplies members to various working groups, subgroups, and subcommittees. This personnel includes Chuck Brinkman, Randy Nanstad, Dave Edmonds and me from the Metals and Ceramics Division (M&C); Pat Callahan, Jim Corum, John Merkle, Sam Moore, and Terry Yahr from the Engineering Technology Division (ETD); and Rocky Hudson and Jim McGuffey from the Quality Assurance and Inspection department (QA&I). Numerous other ORNL staff members contribute to the code in an advisory capacity on special projects or activities. The M&C personnel is concerned with materials specifically mentioned in the ASME code—that is, fatigue; toughness; and tensile, stress rupture, and creep properties. These staff members are also involved in weldability and the extent to which fabrication procedures will affect these mechanical properties. The ETD personnel is involved with Section III, Nuclear Power Plant Components, specifically in the area of high-temperature design; and in Section XI, Rules for In-Service Inspection of Nuclear Power Plant Components. The QA&I personnel are contributors to code activities related to examination and fabrication.

The quality of the ASME code is the basis for its worldwide acceptance, and the safety record of vessels built within its parameters is excellent. Today, 48 states, all the Canadian provinces, and 36 cities or counties have adopted one or more sections of the code, a viable, current document that is reviewed, discussed, and updated six times a year. Committee Chairman Brister attributes the excellence of the ASME code to "... the dedication of those who work so diligently, much of it on nights and weekends, to make a good code even better ..."

Today's pressure vessel codes are refined to the extent that the probability of failure is almost nil—actually to the extent that the news media are on the alert for word of failure of any type of pressure vessel, even a water heater. ornl

letters

Letter to the Editor

The anecdote submitted by Herbert Pomerance in the Spring issue of the *Review* is inaccurate and inappropriate. The incident referred to as "Frank King's story" has to have occurred approximately 30 years ago, which may explain the inaccuracy of Pomerance's memory. Frank King was an active labor union member, as well all others in that shop. All bargaining union members were required by contract to have uniform working hours. Their lunch time was an administrative function of the research shops and was agreed to by the Chemistry Division director and chemistry personnel. I believe that Herbert Pomerance was a member of the Physics Division.

Frank King was not a draftsman assigned to the Chemistry Division. He was a machinist and later classified as instrument maker. I was superintendent at that time, and K. P. Wallace was one of our foremen. The Pomerance version names Wallace as the superintendent's superior. There was mention only of three men, with no mention of Dave Holcomb, who was lead instrument maker and other skilled men in the shop.

These men did not make such statements to management as supposedly stated by Frank King or the quotes from Frank King as an actor trying another tack. These quotes could more likely have developed in someone's mind over a 30-year period. The final quote, "No more was heard from the superintendent's office," really verifies how inappropriate and inaccurate this anecdote was.

I hope these comments will justify my criticism of this particular anecdote and not be considered a rewrite of it.

J. Earl Longendorfer

The author responds:

It was certainly wrong on my part to misplace K. P. Wallace, and I am sorry for any hurt. Even more, there was no need to name him when I didn't name the others on the superintendency side. But having named him (he was a foreman), I should also have named J. Earl Longendorfer and Paul Kofmehl, the assistant superintendent and the superintendent of the research shops.

Many years ago I read of Don Marquis, the creator of Archie and Mehitabel, that there were episodes he was not proud of and would leave out of an account of his life. Conversely, there were episodes that were so characteristic of him that, even though they had not happened, he would include them in the account. Did Frank King really talk that way to Paul Kofmehl? Neither is here for us to ask, but the remark is characteristic of what Frank would have liked to say.

At the end of the war, Clinton Laboratories had perhaps 200 professional people, less than the roll in any of the four largest research divisions today. As the laboratory grew and the big shop came in, there was friction because of the different management and controls between the small and large units. In Portugal, where I visited a gold jewelry factory, I was told that the workshops had from four to six men, no more, because it was easier to supervise by social control in small groups. My story was about social control opposed to control by the book of regulations.

—Herbert Pomerance

Socioeconomic Impacts of Nuclear Power Plants

By CAROLYN KRAUSE

Elizabeth Peele

The March 28, 1979, reactor accident at the Three Mile Island nuclear power plant near Harrisburg, Pennsylvania, had a number of social and economic impacts. Thousands of area residents, including pregnant women and children, fled their homes for a few days; local schools were temporarily closed; stores lost business because many customers and employees had left the scene; people suffered emotional distress due to fears about the hazards of radiation; people worried about possible large increases in their utility bills to pay for reactor cleanup and repair and for replacement electricity; and property values plummeted for a short time. Other impacts include increased tourism and, on the national scale, an intensification of the political debate on the benefits and risks of nuclear power.

It is obvious that the accident's impacts on the communities adjacent to the Three Mile Island reactor will be studied for some time by sociologists, psychologists, and economists. But it is not so obvious or well known that social scientists have been studying the social and economic impacts of proposed and operating nuclear power plants since 1972. Many of these social scientists are from Oak Ridge National Laboratory (ORNL), which pioneered the field of analyzing the social and economic impacts of nuclear power plants on communities.

On July 23, 1971, a federal judge ruled in the landmark Calvert Cliffs decision that the Atomic Energy Commission (AEC) had failed to comply fully with the National Environmental Policy Act of 1970 (NEPA). The judge said that the AEC was required to issue environmental as well as radiological impact statements in support of its licensing actions for proposed and operating nuclear power plants. According to judicial interpretation, these statements must include detailed descriptions of proposed nuclear power plants and independently assess the impact of their construction and operation on the community as well as on the environment. Hence, the AEC had to consider the impacts of power plants on people as well as on plants, animals, and fish.

Mendocino

Oak Ridge National Laboratory was immediately drawn into the massive, frantic task of preparing environmental impact statements for scores of nuclear power plants licensed or about to be licensed by the AEC. In June 1972, Roy Thoma, task group leader, and a team of environmental impact assessment scientists spent a week at Mendocino, a remote town of less than 500 people on the California coast about 130 miles north of San

"Utilities have spent millions of dollars for fish screens without blinking an eye but have balked at spending the same amount for a plan to mitigate impacts on people. These priorities are changing ..."—Peelle

Francisco. Because a site on the Mendocino coast was being considered for the installation of a large nuclear power plant, the ORNL team visited the site after reviewing the applicant's environmental report as part of the impact analysis.

Upon arrival at the site, Thoma became concerned about the large social impact that construction of a nuclear power plant would have on a small, isolated community in a scenic coastal environment. He foresaw the potentially adverse impact of a 3000-man construction force on the community's schools, roads, water and sanitation facilities, and social structure. Several months later, Thoma asked Elizabeth Peelle, a consultant and chemist-turned-sociologist, to join his task group and analyze the social impacts of building a nuclear plant at Mendocino. When Peelle took the job in November 1972, she became the first social scientist to address social questions for the AEC.

With no data, methodology, or guidelines to work with, Peelle undertook the task of assessing power plant impacts on Mendocino in six weeks. "It was an arduous experience," she recalls, saying that she gathered much of her information by telephone. (She did not visit the site until years later on a vacation.) She raised many questions about the need for the utility to provide means for mitigating social impacts. However, the matter became moot when the utility canceled the plant because of concern that the region is subject to earthquakes and because of the passage of Proposition Nine, which called for coastal zone management and forbade construction of power plants in coastal zones.

Peelle's preliminary investigation of social issues raised by nuclear power plant construction was precedent-setting. It looked into the disruptive impacts on a small community of an energy project that required skilled workers living farther away than the normal commuting distance. "Mendocino would have been the first nuclear boomtown," Peelle says. At AEC's request she prepared a summary document in 1973–74 on social impact analysis in light of the Mendocino case. Although unpublished, the document has influenced subsequent studies.

Pilgrim and Millstone

Because of the scant information she had to work with during the Mendocino study, the first social impact assessment of a nuclear power plant, Peelle realized the need to study nuclear communities that had already gone through the construction phase. In 1973, she proposed that ORNL conduct postlicensing studies at operating nuclear power plants to determine what the impacts on the communities have been. She argued that information on property tax revenues, size of the construction labor force, demand for housing, impact on public services such as schools and law enforcement agencies, and reactor-related employment growth would be valuable in projecting social and economic impacts of similar power plants in the proposal stage. Peelle's proposal to the AEC led to a series of postlicensing studies (two at ORNL) and the growth of social impact assessment of energy projects as an applied field in the social sciences.

In 1975, the first postlicensing study of the socioeconomic effects of operating reactors was initiated by ORNL social scientists Bruce Purdy, Peelle, Ben Bronfman, and Dave Bjornstad as a research follow-up to the Mendocino study. The two-year study involved collecting data on sites in Plymouth, Massachusetts, home of the Pilgrim reactor, and Waterford, Connecticut, site of the Millstone I and II reactors, as well as in state offices in Massachusetts and Connecticut.

According to Peelle, the postlicensing study of the two New England communities was "the first of a series of such studies aimed at developing data bases, methodologies, hypotheses, and eventual guidelines for siting through examination of communities which host nuclear reactors." The three-pronged method used to ascertain socioeconomic impacts on these nuclear communities consisted of interviews with citizens chosen randomly from the population, interviews with local leaders and officials, and reliance on secondary data, including statistics on local population, school enrollment, and employment.

Members of the Social Impacts Assessment Group include, sitting from left, Linda Berry, Sam Carnes, Bob Braid, Ben Bronfman (group leader), and Tad Cowan; from left standing are Bob DeVault, Lois Bronfman, Carol Tevepaugh, and Marty Schweitzer.

Plymouth and Waterford were selected for the case study because they are close together geographically and have similar reactors, socioeconomic variables, and regional settings. They differ in population growth rates, use of planning and zoning to control growth, unemployment rates, and median incomes. For example, before the reactor construction period, Waterford controlled its population growth by implementing restrictive zoning ordinances. Waterford's population increased 11% during the eight-year construction period, whereas Plymouth's population increased 11%/year. According to a report by Purdy and Peelle:

"Plymouth suddenly underwent explosive growth beginning in 1968, when construction of the Pilgrim I station began. By 1975, Plymouth had a population of 28,000, a growth rate of about 11%/year since 1968 when the population approximated 16,000. School enrollments increased 108% in the decade to 1975, necessitating

double sessions until three new schools were built in 1975, and building permits doubled each year from 1970–72.

"The new residents are primarily employed outside of Plymouth and chose Plymouth as a desirable place to live for many reasons, including the expectation of 'low taxes.' The oldest town in North America, Plymouth still retains the representative town meeting form of government adopted in 1620. In order to deal with these problems of growth, the town has hired its first full-time planner, executive secretary, and public works director."

The key findings of the New England study were these:

- The impact of construction was considered minor, but many people in both communities recalled that traffic was heavier due to the movement of construction workers. The presence of the construction workers had little impact on commercial activities, although they made purchases at local grocery stores and taverns. Local people found speeding by construction workers to be a problem.
- The operation of a multi-million-dollar power plant assured each community a considerable increase in property tax revenue. Because of the large increase in the tax base, both communities opted to lower the existing tax rates and use the additional revenues from the operating utilities to increase

Civic pride in Baxley, Georgia, sparked the renaming of a shopping center. It's now called Nuclear City Plaza in honor of the Hatch nuclear power plants.

public services and facilities. The lowered tax rate made both towns more attractive to industry and prospective homeowners.

- The majority of residents in both communities expressed favorable attitudes toward the nuclear plants, primarily because of the substantial increase in the tax base of their communities. Although some residents worried about the possibility of a reactor accident or radioactive spill at the plant or during transportation of nuclear wastes, most felt that the nuclear plant was beneficial

Many construction workers employed in building the Hatch nuclear power plants moved into Appling County (or the adjacent Toombs County) and lived in mobile homes. This mobile home park is named after the Altamaha River in Appling County.

economically and presented no worrisome problems.

When asked "Would you permit construction of the nuclear plant again?" of the residents who answered, 72% in Plymouth and 87% in Waterford said yes. A national survey conducted in 1975 by the Harris-Ebasco poll showed that 56 to 75% of the residents in three other nuclear communities favored nuclear power.

Brunswick and Hatch

In 1977, the social impact assessment group in ORNL's Energy Division conducted its second "postlicensing" study, this time in the rural Southeast. The communities chosen hosted the Brunswick I and II nuclear power plants in Brunswick County, North Carolina, and the Hatch I and II plants in Appling County, Georgia. One of the communities studies was Baxley, Georgia, which used to bill itself as the "turpentine capital of the world." With the advent of the Hatch nuclear plants, Baxley residents now call their home town "Georgia's first nuclear city," an appellation which even appears on decals stuck on trash cans.

The Brunswick and Hatch cases were selected for study because of the ways they resemble and differ from the communities hosting the Pilgrim and Millstone reactors in the Northeast. The four nuclear communities are alike in that plant-generated property tax revenues have been very large, representing from 39 to 81% of the host community's (or county's) property tax base. But unlike the Millstone and Pilgrim cases, where the vast majority of construction workers were resident metropolitan commuters, about half of the work forces associated with the Brunswick and Hatch plants moved into the area, many of them with families, because these skilled workers lived well beyond daily commuting range.

Oak Ridge National Laboratory social scientists Mark Shields, Tadlock Cowan, and Dave Bjornstad, who conducted this second postlicensing study, estimated that about 3500 project-related individuals moved into Brunswick County and that a similar number moved into Appling and Toombs counties. The ORNL researchers found that the Southeastern nuclear communities, like their Northeastern counterparts, viewed nuclear plants favorably because of their contribution to the local property tax base. But there is also evidence that nuclear plants are seen as good neighbors because they are perceived as symbols and stimuli of industrial growth. Says Shields:

"Although both plants created certain problems during the construction phase—such as increasing school enrollments, sporadic housing shortages, periodic traffic congestion, and wage inflation—these problems were perceived as minor, short-term difficulties which were outweighed by the plant's economic benefits. This was true not only in Appling and Brunswick counties, but also in Toombs County, which receives none of Hatch's property tax revenues."

Toombs County, which is adjacent to Appling County, is an interesting case. Because of its larger size, a majority of the inmoving construction workers settled in Toombs County. But Toombs residents generally viewed the Hatch nuclear plant as a positive economic stimulus, even though the county government received none of Hatch's property tax revenues and yet had to shoulder the burden of providing services for a large number of construction workers and their families. This positive attitude may have been fostered

The Walden Creek Trailer Court, now abandoned, once housed construction workers and their families when the Brunswick nuclear power plants were being built. In 1975 the Brunswick construction force had as many as 2400 workers, 41% of whom lived in mobile homes.

partly by the fact that Toombs experienced other economic benefits from the plant, such as increases in housing construction, retail sales, income, and employment. But there is more to it than that. In Shields' view:

"The fact that Toombs County receives no property tax revenue from Hatch but is highly supportive of the project suggests that property tax benefits are not a *necessary* condition for high public support of nuclear plants. Apart from the range of other economic benefits provided by the Brunswick and Hatch projects, what, then, accounts for such high levels of public support in these two cases?"

Shields argues that the answer may lie in the ideology of growth. "In both host areas," he explains, "there was a generalized commitment to the value of industrial development. From this perspective, a nuclear plant was viewed as a highly desirable investment in the future that would not only generate certain short-term economic benefits, but would also stand as a symbol of growth and a 'good business climate' to industries which might be considering where to locate new plants."

The presence of the nuclear projects may have contributed to political disputes over land-use planning and growth management in Brunswick County, which moved toward increasing specialization and professionalization of administrative functions to cope with new demands on its governmental organizations. As in Plymouth and Waterford, with the desired growth comes growing pains which often are felt by governmental bodies.

In both postlicensing studies, ORNL researchers found evidence of the controversial issue of fiscal equity—that is, the "tug of war" between political entities over how to spread the tax benefit of nuclear plants. Says Shields:

"In both Plymouth and Waterford's neighboring communities, there was resentment that the property tax windfall accrued solely to those host communities, and in both Massachusetts and Connecticut, bills were introduced in the state legislatures to redistribute utility property tax revenues more evenly throughout the states.

"In Brunswick County, the fiscal equity conflict arose as an intense city-county conflict over annexation. In 1977, Southport—the former county seat and the county's major population center—tried unsuccessfully to annex land occupied by the Brunswick nuclear plant and thereby enlarge its own tax base at the expense of the rest of the county.

"In Appling County, the fiscal equity issue emerged in connection with the transfer of a 20% share of Hatch from the Georgia Power Company—the major owner of the plant and the county's largest taxpayer—to two public utilities, both of which are exempt from property taxation. Two county governmental bodies filed a joint lawsuit in 1978 against one of the public utilities claiming that its nontaxable status is unconstitutional, and the county's representative to the Georgia House introduced legislation to remove that public utility's tax-exempt status."

Shields compared the nuclear host areas assessed by ORNL with boomtowns produced by energy development in small, remote areas of the western United States. "Boomtowns and the nuclear host areas we have examined may face similar types of problems—traffic congestion, housing shortages, more crime, and overutilized public services—but in boomtowns the much higher rate of growth tends to produce these problems in a far more acute form. The boom town syndrome could occur in any region of the country and at many types of large projects if the spatial and demographic relationships between a host area and its labor market were similar to those found in the West. However, the boomtown syndrome is not likely to be experienced by many nuclear host communities because about 85% of the nuclear power plants in this country are within 60 miles of the central city of a metropolitan area."

Hartsville Survey

By 1975 the social impacts assessment group headed by Peelle was only one of many groups working in the fast-growing field of social impact analysis of energy projects. Peelle was besieged with visitors who sat in on her "show-and-tell" sessions and with requests for information on this work—continuing at a steady rate of about 100 per year. The burgeoning group of social scientists who dealt with practical questions as they attempted to quantify power plant impacts became mavericks, somewhat isolated from their academic fields which are largely concerned with theoretical questions.

In January and August of 1975, ORNL's social impacts assessment group surveyed residents' attitudes toward the plans of Tennessee Valley Authority (TVA) to build a four-unit nuclear power plant near Hartsville, Tennessee. A panel of 288 residents from Hartsville and Trousdale counties were interviewed in January and reinterviewed in August in 1-hr question-and-answer sessions conducted by trained local residents. The results of the longitudinal survey follow:

- There were more than twice as many supporters as opponents of the Hartsville plant, which at the time was in the planning and prelicensing stage; 31% opposed construction, 69% said that if they could decide, they would permit the facility to be built.

- Most supporters of the nuclear plant favored a coal-burning facility if such were proposed to be built instead of the nuclear facility, while most opponents of the nuclear plant also opposed a coal-burning plant.

- Respondents considered it likely that construction of the nuclear plant would bring about growth-related changes, some good and some undesirable. Plant supporters rated it likely that there would be economic expansion accompanied by such desirable changes as increases in business, tourism, jobs, and industrial development. Supporters also rated social disruption likely but indicated that they were willing to put up with traffic congestion, crowded schools, increased noise, and crime for the sake of economic expansion. Opponents said they did not consider the benefits of economic expansion worth the social costs and/or risks such as radiation and thermal pollution.

- A majority of the farmers and farm workers interviewed opposed the plant. Peelle suggests that one reason so many farmers opposed the plant could be that they feared or had experienced losing hired help to higher paying jobs with the power plant construction force. Wage inflation is a common problem in rural areas where a large power plant is under construction.

- Support was well over 70% among males, blacks, and employed persons, but only about 60% of women and unemployed persons approved the Hartsville facility.

- Respondents' opinions on the plant were basically the same from January to August and seemed to depend on the effects they expected the power plant to have on the community. The size of the plant seemed to have more impact on attitudes than whether the energy source is nuclear, coal, or some other fuel.

ORNL researchers conducting the citizens' survey study were Eric

Sundstrom, Joyce Costomeris, Bob DeVault, Dave Dowell, John Lounsbury, Tom Mattingly, Emily Passino, and Peelle. Following the citizens' survey, Ben Bronfman conducted a survey of Hartsville area leaders to determine their attitudes toward the TVA nuclear project. Bronfman found that 100% of the leaders favored the plant, compared to 65 to 75% of the area population surmised to be in support of the plant.

Hartsville Mitigation Plan

During a nuclear plant's construction period, it is quite possible that adverse socioeconomic effects could pose a serious problem to surrounding communities. In regulations issued by the Council on Environmental Quality in November 1978, NEPA is interpreted to require that environmental impact statements discuss means to avoid, rectify, reduce, eliminate, or compensate for adverse impacts. Such discussion might include proposals of appropriate measures to alleviate the situation. These proposals would comprise what is called a "mitigation plan."

The final environmental statement on the Hartsville project, issued by TVA in 1975, included one of the first mitigation plans ever proposed for communities to be affected by nuclear plant construction. The plan describes what TVA could do to reduce certain adverse socioeconomic effects associated with "the influx of movers, housing, transportation, education, health and medical facilities, water and sewer facilities, planning and coordination as well as local government budgets." Peelle, who has a major interest in the new field of community mitigation planning, was asked by a Nuclear Regulatory Commission (NRC) lawyer (who had sat in on one of her show-and-tell sessions) to evaluate TVA's mitigation plan at the 1975 hearings in Nashville, Tennessee, on NRC's and TVA's final environmental statements. She testified that TVA's mitigation plan was the "most elaborate, comprehensive plan I had ever seen" but suggested that a monitoring plan be put into effect to make frequent checks on population changes and the concomitant impacts of growth on schools, housing, transportation, medical services, roads, water and sewer facilities, and local government budgets. As a result of her testimony and that of others, the NRC licensing board granted TVA a limited work authorization on the condition that it implement its mitigation plan and also monitor, evaluate, and report on the effectiveness of the plan on a semiannual basis during construction and for 18 months after issuance of the last operating license.

TVA's $10 million mitigation plan, which has been in effect for three years, is designed to assist Hartsville and other communities in a five-county "impact area" in providing public services for an estimated 2700 construction workers expected to move into the area by the time construction is at its peak. In implementing the plan, TVA allocated funds for school facilities to accommodate additional students from the families of construction workers. To encourage commuting and reduce the number of construction workers that might consider moving into the project area, TVA instituted an elaborate employee transportation plan involving buses, van pools, and car pools. It is providing assistance for health and medical services, local government budgets, planning and coordination, housing, resident training, and sewage systems.

It is interesting to note that when the construction license was granted and mitigation plan formulated, TVA projected a peak construction staff of 5300 workers. Actually, 6800 workers were employed in early 1979 before TVA Chairman David Freeman announced the postponement of construction of two of the four Hartsville units. This discrepancy between the projected and actual peak construction force is consistent with the findings of ORNL's Bob Braid, who has found that utilities underestimate the construction work force needed by 20 to 40% or more. Such underestimation gives community leaders and social scientists poor data to work with and makes it difficult for communities to predict and prepare adequately for socioeconomic impacts of power plant construction.

With the cutback in nuclear construction at Hartsville, TVA's work force of 6800 will drop to 5000. This cutback will have only a minor effect on the mitigation plan, Peelle says, noting that traffic will be eased and that TVA's school payments will be reduced because these payments are tied to the number of construction workers moving into the area. But TVA's allocations for permanent facilities, such as school buildings and water and sewer systems, will not be affected by the reduced work force.

Cherokee Mitigation Plans

Some time after the NRC had issued its final environmental statement in 1975 projecting very little socioeconomic impact from the proposed Cherokee Nuclear Station now under construction near Gaffney, South Carolina, local and state officials became concerned that more substantial impacts, perhaps of a boomtown nature, might be forthcoming in Cherokee County. They

Baxley, Georgia once billed itself as the "turpentine capital of the world." But after the Hatch nuclear power plants were built, Baxley residents called their hometown "Georgia's nuclear city," as shown on this decal stuck on a trash can.

approached the Appalachian Regional Commission, which, in conjunction with the South Carolina Appalachian Council of Governments, sought the expertise of ORNL's social impact assessment group. Peelle, Martin Schweitzer, Philip Scharre (from the University of Tennessee's Graduate School of Planning), and Bradford Pressman (from Denison University) undertook the task of assessing Cherokee County impacts anew in light of Duke Power Company's changed schedules and work force plans for the Cherokee Nuclear Station. The results of that study, funded by the Department of Energy (DOE), are given in a recent report [*A Study of the Cherokee Nuclear Station: Project Impacts, Monitoring Plan,* and *Mitigation Options for Cherokee County,* by Elizabeth Peelle, Martin Schweitzer, Philip Scharre, and Bradford Pressman (1979)].

Construction of the Cherokee plant, which began in 1976, is expected to be completed by 1989. During that time, the construction force is expected to exceed 2000 most of the time, peaking at 3500 workers in 1985. After several site visits and reviews of numerous South Carolina studies and documents, the ORNL group concluded that: "Housing, public service delivery, income, employment, land use and public finance will all feel the effects of the new facility. The magnitude of these impacts and the extent to which they disrupt or benefit Cherokee County can be modified by carefully designed mitigation strategies."

The ORNL group projected that, during construction and early operation, there would be 1075 additional dwelling units and 690 additional school children requiring government services, serious traffic problems due to a doubling of work-related traffic, up to 750 new jobs for local residents created directly or indirectly by the plant, and higher wages, which could bring higher prices to aggravate the financial problems of individuals living on low or fixed incomes. Belatedly compensating for some of the burdensome impacts on the Cherokee County government will be the dramatic increases in property tax revenues expected beginning in 1986. Such a windfall could allow the county government to lower property taxes while increasing public services, including schools, water, sewage treatment, and police and fire protection.

The ORNL report identifies a need for mitigation measures because the Cherokee County government will not be receiving significant tax revenues from the utility until well after the peak construction period, when the burdens on social services are the heaviest. According to the report: "The negative impacts of this time lag, whereby public funds will be required for the expansion of various services before Duke Power Company begins to pay property taxes on the improved value of its holdings, can be addressed through appropriate mitigation measures."

Choice of the appropriate mitigation strategy is contingent on forecasts of population growth primarily from new residents. In the Cherokee case, population is expected to grow first because of the creation of plant-related jobs and second because of the new residents attracted by the anticipation of lower taxes and better services. Since population forecasts are fraught with uncertainty, ORNL suggests that community changes induced by the nuclear construction project be continuously monitored by the county so that mitigation plans can be implemented before adverse impacts become unmanageable. The report spells out four options available to Cherokee County: (1) doing nothing; (2) preventing growth; (3) selective growth; and (4) maximum growth. The 1979 ORNL report suggests federal or state programs as well as various self-help efforts that might aid the county if it chooses a growth management plan requiring mitigation measures. So far, Cherokee County has not decided which option to pursue.

On May 19, Duke Power Company announced a two-year postponement of the completion of the first two units because of difficulty in raising capital. Martin Schweitzer of ORNL says that, insofar as postponement reduces work force, the group's projections would also be affected.

Future Directions

The social impacts assessment group, now headed by Bronfman, has worked on more than 25 social impact assessments of nuclear power plants, coal facilities, uranium mines and mills, and the expansion of DOE facilities in Oak Ridge. The group would like to do more surveys, longitudinal studies, and hypothesis testing, but the U.S. Office of Management and Budget's reluctance on attitude studies and government emphasis on long-range generic assessments have made it difficult to obtain funding for other types of study projects. Bronfman and others proposed a 10-year longitudinal study of citizen attitudes toward the Hartsville project before, during, and after construction, but DOE lost interest in the study after three years and dropped its funding. Even so, the ORNL group submitted a proposal this year to resume this longitudinal study because the results would be helpful in evaluating the accuracy of original projections of impacts and because no other longitudinal studies have ever been completed.

Peelle would like to resurvey citizens' attitudes in the nuclear communities previously studied by ORNL to determine if these attitudes have changed since the Three Mile Island accident.

"The Three Mile Island accident is a discontinuity," she says. "It has altered the public's perceptions of the benefits and harms of nuclear power. A *New York Times*/CBS news poll in April 1979 showed that only 46% of Americans now favor further development of nuclear power compared with 69% who were asked the same question in a July 1977 poll. We need empirical studies to determine which of two contradictory trends is going to predominate.

"The first trend is that the nuclear accident triggered a widespread feeling of dread and fear because it left the impression that the reactor was out of control, that the plant operators did not know what they were doing, and that the plant managers were unable to give the public and local government officials accurate or timely information on radiation doses or the potential for future radiation releases to people living near the reactor.

"The other phenomenon is that attitudes toward anything tend to be persistent regardless of new facts or changes. Once people have made up their minds, they tend to close them to new information that could refute what they have come to believe. We found that, once people in Plymouth and Waterford learned about the tax benefits of nuclear power plants, they were less receptive to information about nuclear hazards. Will their perception of Three Mile Island events change this? So far we have only little hints of information on this question. For instance, when a reporter from the Hartford *Courant* informally surveyed randomly chosen members of the Plymouth and Waterford populations after the Three Mile Island accident, he told me that he found no significant attitude changes."

Peelle would like to see utilities and government agencies devote more time and money to assessing social impacts of power plants and reducing these impacts where possible. "I have seen environmental impact statements that devote thousands of pages to the problems of and possible solutions for biota protection at power plants but only two or three pages to analysis of impacts on people. Utilities have spent millions of dollars without blinking an eye for fish screens but have balked at spending the same amount for a plan to mitigate impacts on people. These priorities have changed considerably since we began working in this area, but I believe that more needs to be done." ornl

Staff Quote:

"Equipment is generally excellent. However, the number of job slots is limited and not specified as to level. Therefore, the tendency is to hire Ph.D.s and there is (a) a low ratio of technical help to Ph.D.s, and (b) virtually no secretarial or editorial help. Scientists do all of their own typing, and they draft and photograph their own figures for publications or slides . . .—Liane B. Russell, commenting on her visit this year to the National Institutes of Radiological Sciences and Genetics at Chiba and Misima, in Japan.

achievement

Cermets for Storing Nuclear Wastes

The public acceptability of nuclear power is partly contingent on assurances that high-level radioactive wastes can be safely and permanently isolated. The traditional and most favored approach to waste disposal has been to incorporate radioactive materials in blocks of glass, seal the blocks in metal canisters, and place the canisters into underground salt beds. Now, researchers are also testing newer ceramic forms for waste storage to determine their durability at high temperatures and pressures in brine, simulating the extreme conditions that might prevail in the highly unlikely case that water penetrates a salt bed burial site. Under such conditions, it is important that the waste matrix be resistant to leaching by water to prevent highly radioactive substances from being carried beyond the disposal site.

Scott Aaron, Tom Quinby, and Ed Kobisk of ORNL's Solid State Division have developed a new waste matrix that appears to be more durable than glass in harsh environments and has several other advantages over vitreous and other ceramic waste forms. The new matrix is called a cermet because it consists of tiny ceramic particles of fission product oxides or other compounds that are embedded homogeneously in a metal alloy. A unique feature of the cermet is that the iron-nickel alloy makes use of metals in the liquid waste itself as well as some added ones obtainable at essentially no cost from government stockpiles of contaminated materials, thus improving the economics of the process. The unique characteristics of the cermet are obtained by chemical coprecipitation of waste and additives from molten urea, the common organic material used for making fertilizer. Urea destroys nitrate ions formed by dissolving wastes in nitric acid. During precipitation, innocuous gases such as nitrogen, hydrogen, ammonia, carbon dioxide, and water vapor are released. The precipitate is calcined to remove all the urea and to convert the fission products to oxides, aluminosilicates, titanates, and other ceramic forms. Hydrogen-reducible metal ions such as nickel, cobalt, and copper, added to the waste before urea precipitation, are atomically mixed in the powdery precipitate. Upon reduction of the calcine, the metals form a "microencapsulation" of the nonreducible ceramic phase in an iron-nickel base alloy which is subsequently compacted into a high-density matrix upon extrusion and sintering.

What are the advantages of cermets? Preliminary studies show that cermets are considerably more resistant to leaching by water at 100°C than a borosilicate waste glass. The metal alloy can be tailored to make the waste form compatible with a variety of storage environments and conditions. Cermets, in the form of bars or rods, show high mechanical strength and corrosion resistance. The metal matrix exhibits high thermal conductivity; hence, since cermets dissipate heat more readily than other waste forms, higher waste loadings per unit volume are feasible. The process of urea precipitation results in practically no radioactive species in the gas phase during processing other than by incidental entrainment. The resulting cermet volume is a factor of 2 to 200 smaller than the original volume of waste being treated. Also, if the cermets are made with the iron-nickel alloy, they can be moved by magnets and placed in storage.

Recent studies have shown that a specially tailored Hastelloy cermet is the only waste form to date that can withstand the brine environment that might occur from the penetration of water into salt beds at the extreme temperature and pressure conditions of 350°C and 1550 Pa.

Wastes being considered for fixation as cermets are those of commercial fuel reprocessing facilities, such as the Nuclear Fuel Services plant in West Valley, New York, and Department of Energy defense wastes stored at Savannah River, South Carolina, and Hanford, Washington.

The process is based on technology previously developed for the preparation of special ceramic neutron dosimetry materials for reactor core characterization. Quinby, a senior technologist who holds two patents on the process, has dubbed the process "Cermet Retention for Underground Disposal"—CRUD, for short.—C.K.

awards and appointments

The Nuclear Division won five IR-100 Awards this year, four of which represent work performed by ORNL staff: Ductile Ordered Transition-Element Alloys, by **Chain Liu, Hank Inouye,** and **Tony Schaffhauser;** Low-Cost Laser-Diffused Solar Cells, by **Jagdish Narayan, Rosa Young, Dick Wood, Russ Westbrook, Woody White,** and **Warren Christie**; the Gel-Sphere-Pac Nuclear Fuel Fabrication Process, by **Jack Lackey, Peter Angelini, Ray Beatty, John Begovich, Tony Caputo, Ralph Donnelly, Paul Haas, Frank Harrington, Claude Haws, Jim Horak, Fred Kappelmann, Rex Leuze, Milt Lloyd, Ernie Long, Pete Lotts, Jim Mack, Roy Norman, Karl Notz, Arvid Pasto, Al Ryon, Roger Spence, Dave Stinton, Bob Suchomel,** and **John Vavruska;** and the Tapered Fluidized Bed Bioreactor, by **Chuck Scott, Chuck Hancher,** and **Douglas D. Lee. Larry Howington**, Y-12 Development Division, was also a winner for his Microcomputer-Based Video Motion Detection System. This year's presentation marks Scott's fourth IR-100 Award.

Dave Novelli, while on a speaking tour in Europe last summer, was elected to membership in the Lombardy Academy of Medicine in Milan, Italy.

Rufus Ritchie has been named Corporate Research Fellow by Union Carbide Nuclear Division.

Enzo Ricci has been appointed to the American Nuclear Society's National Planning Committee.

Ray Wymer has been appointed to a three-year term on the Subcommittee on Nuclear and Radiochemistry of the National Research Council.

Phil Fairchild has been nominated to serve on the Heat Pumps Advisory Group of the Gas Research Institute.

W. D. Shults has been chosen to be chairman-elect of the Division of Analytical Chemistry in the American Chemical Society.

Noah Johnson and **Gayle Painter** were recently elected fellows of the American Physical Society.

At the International Technical Communication Conference in May, the Award of Excellence (second place) in the Handbooks and Manuals category was given to "Environmental Monitoring Handbook for Coal Conversion Facilities," by **Marti Salk, Steve DeCicco,** and the **ORNL Technical Publications Department.**

Elected to the rank of fellow in the American Nuclear Society were **Tex Blomeke, Jim Horak, Bill Cottrell,** and **Don Steiner.**

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A view of the harbor on the saltwater inlet at Southport, North Carolina, home of the Brunswick I and II nuclear power plants. The socioeconomic impacts of the plants during and after construction were studied by ORNL researchers. *See article on page 36.*