Winter 1982

Oak Ridge National Laboratory

review

THE COVER: This spectacular spark from the positive terminal of the 25 MV tandem accelerator at the Holifield Heavy Ion Research Facility occurred at a voltage of 22 MV. In addition to producing the highest steady voltage difference ever generated by man, the Holifield accelerator has achieved other world records and has produced interesting results in early experiments, as described in Information Meeting Highlights on p. 18.

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Departments

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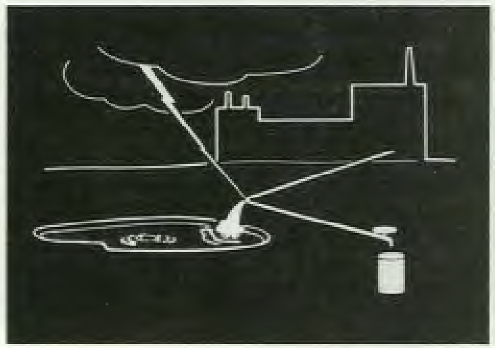
Whenever an accidental spill occurs, ORNL is obliged to find out what was spilled and where it came from and then to stop the spill. ORNL's quick response team of chemists can rapidly determine what type of oil was spilled or whether the oil contains hazardous PCBs. Research led by Mike Maskarinec, at left with a gas chromatograph, is aimed at analyzing hydraulic fluids for toxic organics that could be discharged accidently to ORNL streams.



ORNL's Quick Response Team:

Analytical Chemists on Call

By CAROLYN KRAUSE

Last year, a transformer in the Instrumentation and Controls Division exploded during a testing procedure and sprayed oil on nearby workers. The first concern was whether the oil from the ruptured transformer constituted a health hazard. A team of analytical chemists was asked to determine quickly whether the oil contained polychlorinated biphenyls, a health hazard if ingested. Soon after the workers showered and changed into clean clothes as a precaution, the chemists obtained a gas chromatographic profile of the oil and found, to everyone's relief, that the oil contained no PCB.

One day in March 1981, Joe Stewart was roused at 6 AM by a ringing telephone. Tom Oakes, ORNL's environmental coordinator, was calling from Knoxville to inform Stewart that White Oak Creek behind Building 4500-S had suddenly turned green. Oakes requested the assistance of the Analytical Chemistry Division in identifying the material coloring the creek.

Stewart, ORNL's emergency response coordinator for nonradioactive events, telephoned several chemists and asked them to identify the contaminants in the creek. They determined that the creek color was the result of the presence of a fluorescent dye normally found in ethylene glycol, an air-conditioning coolant. Some more detective work by Brian Kelly in Oakes' group tracked down the source: a cracked coil in the air conditioning equipment in the High Voltage Accelerator Laboratory. The leak

Kaye Webb and Fred Rogers check peaks in a book of oil profiles. The profiles, used in ORNL's oil identification program, were made at ORNL by running samples of the 40 different oils in ORNL's inventory through a gas chromatograph. By comparing the profile of an oil found as a visible sheen in ORNL waterways with the book profiles, analytical chemists can determine whether ORNL is responsible for the oil spill.

was repaired, preventing further loss of glycol fluid, which can lower dissolved oxygen content in waterways and possibly kill fish.

Also last year, some oil was found in the dirt and leaves near an ORNL cooling tower. This material was eventually washed into the creek. Fortunately, analytical chemists had just completed the job of obtaining gas chromatographic "fingerprints" on the 40 different types of oil purchased by ORNL. By identifying the type of oil and checking out the equipment known to use this type of oil in the area of the spill, the chemists found that the oil came from a tractor. This incident was the first test of the Laboratory's oil characterization program for identifying oils found on the ground and as visible sheens on creeks, rivers, and lakes. Later in 1981, several minor visible sheens were traced to ORNL equipment. Called to action by Stewart, the quick response team of analytical chemists identified the oil in each incident, which allowed Oakes' department of environmental management to track down the source.

Quick response to unusual incidents involving radiation has been an ORNL capability since 1960, but a system for rapid response to nonradioactive events such as oil spills and hydraulic fluid leaks has been in operation only for the past two years. W. D. Shults, director of the Analytical Chemistry Division, originated the concept of a quick response system for nonradioactive events and appointed Stewart as emergency response coordinator. Stewart's job is somewhat analogous to that of Jim Eldridge, emergency sample coordinator in the Analytical Chemistry Division, who deals with radiochemical events (see box).

"Our goal," says Stewart "is to develop tests that can identify hazardous chemicals in spilled material within four hours. We have the capability of identifying oil spills, analyzing for PCBs in water and organics and for toxic metals in water, identifying organics, and measuring biological and chemical oxygen demand. Fortunately, this quick response service has not been needed often. We hope that the service is never needed in the future, but we must be prepared because occasionally things go wrong."

The efforts of the division to develop and implement analytical

Charlie Coley, technician, rests a sample of PCB-contaminated oil on a gas chromatograph equipped with an electron capture detector. This apparatus is used to identify and quantify polychlorinated biphenyls in waste oil, spilled oil, and oils used as dielectric fluids in ORNL transformers. Looking on is Hershel Davis, who played an important role in reestablishing the method now used for PCB analysis in oils.

procedures to quickly identify potentially hazardous chemicals and their sources have earned it special recognition from the Laboratory's environmental coordinator. Recently, Oakes presented to Shults and the Analytical Chemistry Division the first ORNL Environmental Protection Award. Separate plaques were given to Bruce Clark and Fred Rogers, for development of the oil characterization program; to Hershel Davis and Bob Rickard, for reestablishment of a procedure for rapid analysis of PCBs in oils; to Harris Dunn, Bob Sherman, and Stewart, for the development of a system for quantitative determination of asbestos in construction materials; to Jim Eldridge, Tom Scott, and Jim Stokely, for developments in detection of radioactivity in environmental samples; and to Stewart, for coordination of specific environmental analyses.

Oil Characterization

Rapid response programs to manage events involving chemicals have been developed as a result of environmental legislation enacted in the 1970s. ORNL has set up a quick response capability to help it comply with such laws as the Clean Air Act, Clean Water Act, Occupational Safety and Health Act, Resource Conservation and Recovery Act, and Toxic Substances Control Act. For example, if a visible sheen appears on a creek on the ORNL reservation, the Clean Water Act requires that the oil spill be reported immediately to the Department of Energy and the Environmental Protection Agency. ORNL must then determine quickly if the oil is being discharged from one of its facilities and, if so, take immediate action to contain the spill.

ORNL, however, will not be blamed for the oil spill if its analytical chemists can identify the oil and show that this type of oil does not exist in the Laboratory's inventory, or that no equipment having this type of oil is leaking. The oil may have been discharged upstream from ORNL by another institution or industry, or it may be crankcase oil from automobiles. Thanks to ORNL's new oil characterization program, the Laboratory can positively identify samples of oil from nearby lakes and creeks and determine whether or not ORNL is the source.

In the 1970s, the Coast Guard adopted various techniques for detecting oil spills on the open sea. (Oil spills are an environmental hazard because birds wetted by the oil-water mixture drown and because the oil ruins beaches.) In preparation for setting up an oil characterization program at ORNL, Bruce Clark, Leon Klatt, and Stewart searched the scientific literature for oil spill detection techniques that had been used by the Coast Guard or research centers over the past five years. Clark noted that the simplest methods to obtain a fingerprint of a given oil included gas chromatography (GC) or infrared (IR) spectrometry. Clark and Fred Rogers, therefore, proceeded to try GC and IR profiling of samples of all 40 types of oil in ORNL's inventory. When they finished, the team was pleasantly surprised to find that even crude GC techniques were sufficient to distinguish among all 40 oil types.

To fingerprint an oil sample, ORNL chemists extract the oil with a solvent and inject a few microliters of the solution into a column heated to 400°C. As the compounds vaporize, helium gas "washes" the oil vapors through the column. Because of differences in their physical-chemical properties, the compounds tend to separate and emerge from the end of the column at different times. Compounds are detected and recorded as they emerge, producing a series of peaks which make up a reproducible fingerprint.

After finding that the profiles for ORNL's 40 oils are distinguishable from one another, Clark and Rogers recommended that the Laboratory set up a "library" of oil profiles. Such a library was established; now, when a GC profile is obtained for an unknown oil, the oil can be

(continued on p. 6)

Jim Eldridge hurries out the door of Building 4500N with his Samsonite suitcase to a simulated radiation emergency. He is joined by his assistant, Norm Teasley, who helps him open the suitcase and set up the computing gamma spectrometer to take readings on a water sample. The spectrometer is used to screen water, soil, grass, and air samples for radioactivity in the vicinity of real and simulated emergencies involving the possible release of radioactivity.

Detecting Radioactivity in Environmental Samples

When a simulated or real release of radioactivity occurs in the Oak Ridge area, radiochemist Jim Eldridge is usually called to the scene of the accident by ORNL's environmental coordinator. He arrives carrying a Samsonite suitcase, which disguises its contents—a portable gamma-ray spectrometer complete with microcomputer. With this instrument, he will check for environmental radioactivity in air-filter paper, soil, grass, and water samples. The gamma-ray spectrometer not only can detect radioactivity but also can identify the radionuclide source, whether it be cobalt-60, cesium-137, iodine-131 or any other gamma-ray emitter.

If radioactivity is detected, Eldridge then assumes his role as ORNL's emergency sample coordinator and directs the samples to three labs at ORNL for quantitative analyses of the detected radionuclides. These labs, run by Juel Emery, Tom Scott, and Eldridge (all of the Analytical Chemistry Division), have instruments for alpha, beta, and gamma counting and for radon-tritium measurements. Quantitative analyses of environmental radioactivity give an approximation of radiation doses to people in the vicinity of the accident.

Some of Eldridge's most exciting moments have come when he has been called for offsite radioactivity measurements. Shortly after the March 28, 1979, accident at Three Mile Island nuclear power plant, Eldridge joined ORNL's environmental management staff and DOE's Oak Ridge Operations in checking the TMI environment for radioactivity. Eldridge found no evidence of radioactivity near the populated areas. What made the trip exciting was his opportunity to enter the TMI control room on the same day that President Carter visited it.

In September 1980, Eldridge and a team of ORNL environmental management staff were placed on alert to provide offsite radioactivity measurements and monitoring at the Arkansas site where a Titan missile exploded. The ORNL team and equipment were ready when word came that they were not needed because tests indicated that the nuclear warhead on the missile was intact, nullifying the possibility of radioactive releases to the environment.

Eldridge has had few onsite radiological emergencies to handle. Occasionally, unusual releases of radioactivity from the stacks of ORNL's research reactors occur, but the radioactivity detected in environmental samples following these incidents has been negligible. Eldridge recalls an incident in the early 1970s when an accused home burglar was apprehended near Melton Hill Dam. Because the young man was believed to have walked in the vicinity of White Oak Dam and White Oak Creek, which are slightly contaminated, Eldridge was summoned to check the man's clothes and boots for radioactivity. He found some evidence

of radioactive cobalt on the man's belongings, but this was not considered a hazard to his health.

Most of the time that Eldridge spends as emergency sample coordinator is devoted to simulated incidents. In June 1981, he attended a drill at the Federal Building (DOE's Oak Ridge Operations) to rehearse emergency responses to a simulated release of radioactivity to the Oak Ridge environment from ORNL's High Flux Isotope Reactor. In July 1981 Eldridge participated in an annual drill involving DOE and regional utilities at the Sequoyah nuclear power plant, site of a simulated nuclear incident. In both simulated incidents, everything went well with the equipment except for battery and fan belt problems in the DOE emergency response van.

On September 15, 1981, an emergency drill was held at ORNL to rehearse the responses of shift supervisors, firemen, health physicists, radiochemists, and a medical team to a simulated nuclear criticality accident. In this scenario, an error in handling of uranium metal cubes in a storage vault (Building 3027) resulted in their being inadvertently stacked in an unsafe geometry, triggering fission but no release of radioactivity to the environment. One person received a lethal dose in this simulation, and six others were exposed. Eldridge was prepared to check environmental samples with the gamma-ray spectrometer, but instead he was asked to use this instrument for scanning victims. Because ORNL has only one whole-body scanner and because there were so many victims in the simulated accident, Eldridge's spectrometer was urgently needed as a backup to the whole-body scanner.

"The portable gamma-ray spectrometer can be used to determine radiation doses to victims," says Eldridge. "If a person is exposed to a high level of neutron radiation, radioactive sodium (^{24}Na) is formed in the blood. Because ^{24}Na is a gamma emitter, we can detect it by scanning radiation victims with the gamma spectrometer. Metal buttons or coins or tools on a person exposed to neutrons will also be activated—that is, gamma radioactivity will be induced in these things. By measuring this radioactivity with our portable instrument, we can determine the precise neutron radiation dose received by that person."

Eldridge hopes that more simulated incidents will be held so that emergency response teams can be better prepared for actual incidents. He also hopes that funds will be available for outfitting an 18-wheel trailer and cab with radiation survey instruments; this vehicle was provided to ORNL by DOE for offsite emergency response and onsite environmental measurements. Eldridge, after all, is a strong advocate of planning for unplanned releases. —C.K.

Mike Maskarinec and technician Wallace Harvey extract organic chemicals from a water sample. Maskarinec then concentrates the organics to a factor of 1000 of what was present in the water sample and injects 1 mL of the highly concentrated organic material into a gas chromatograph for analysis. The chemical content of the material is further pinned down by running it through a mass spectrometer and gas chromatograph again.

identified by matching its profile with one in the library.

PCBs in Oils

The hazard of exposure to polychlorinated biphenyls first came to the world's attention in the late 1960s when 12,000 Japanese became ill. Their symptoms included skin pigment changes, swollen eyelids, hair loss, hearing difficulties, swollen limbs and joints, vomiting, diarrhea, and headaches. Some people died, and many pregnant women later gave birth to children who had severe skin problems. The outbreak was traced to a mix-up at a company that produces both PCB oils and cooking oil. As a result, thousands of Japanese unknowingly ate rice cooked with PCB-contaminated oil.

In the 1970s, outbreaks of PCB poisoning in children occurred in the United States, notably Michigan, where PCBs discharged by industry into rivers and lakes found their way into cows' milk and ultimately into mothers' milk. Recent research on animals indicates that PCBs are suspected carcinogens as well as poisons.

Under the Toxic Substances Control Act of 1976, the EPA is required to regulate numerous toxic substances, including PCBs. Manufacture of PCBs has been prohibited in the United States since 1976, but PCBs are still around because of their previous use as dielectric fluids in electrical transformers. EPA now regulates the sale and disposal of oils that may be contaminated with PCBs.

How does this affect ORNL? In 1978, Union Carbide Corporation's Nuclear Division started a program of sampling transformers and other equipment to determine which equipment at ORNL and the other three UCC-ND plants contained PCB oils. The goals of this effort are to discard all PCB oils, to replace these oils with mineral oils in some transformers, and to replace other dielectric fluid transformers with dry transformers.

The other major problem encountered by ORNL and the other UCC-ND plants is disposal of PCB oils. Oil can be sold off site if its PCB content is less than 5 parts per million. Any oils containing more than 5 ppm, however, must be disposed of safely. Currently, ORNL is storing PCB-contaminated oils in EPA-approved containers until they can be shipped to an EPA-approved landfill for disposal. The long-range goal of UCC-ND and DOE's Oak Ridge Operations is to destroy these oils in an incinerator to be built and operated at Oak Ridge Gaseous Diffusion Plant by 1987 if funding is approved.

To determine the PCB content of samples of transformer dielectric fluid and waste oil, ORNL reestablished a system for PCB analysis two years ago. (Previous PCB studies had been done on a small scale in the early 1970s.) This method of routine analysis for transformer oils has been adapted for quick response to several minor crises in the past year:

Item. As mentioned before, workers were sprayed with oil when an Instrumentation and Controls Division transformer ruptured. PCB analysis of microliter-sized samples taken with hypodermic needles indicated that the oil contained no PCBs and was therefore not a health hazard to the workers.

Item. After discovering that fish in Melton Hill and Watts Bar lakes have a high PCB content, the EPA and the state of Tennessee have questioned whether ORNL is the source of the PCBs in area waterways. Chemical analyses at the

Laboratory indicate that no recent discharges from ORNL contain PCBs.

Item. During a plantwide survey of all oil-containing equipment, a machine in the Metals and Ceramics Division was found to contain PCBs. This oil was inadvertently obtained in 1968 as a substitute for the phosphate oil specified in the purchase request. The equipment was idle at the time of the initial survey but was used in September 1981 in a demonstration for DOE. During this operation, oil found to contain 96% PCBs leaked from the machine into a contained sump whereupon the equipment was cleaned and flushed of PCB-containing oil.

Hershel Davis and Bob Rickard set up the system that analyzes for PCBs in trace amounts as well as substantial quantities. Both quick response and routine analyses are accomplished by gas chromatography combined with an electron capture detector, which is sensitive to the chlorine in the polychlorinated biphenyls. The resulting fingerprint is compared with those of PCB standards to identify the particular PCB present in the oil, and ratios of peak heights or peak area between samples and standards are used to quantify the PCBs.

ORNL researchers have assembled a book of nine standard PCB curves and identified five major commercial PCB mixtures in fluids in ORNL equipment, including PCB 1254 and PCB 1260, which are common in transformers. Their system is capable of detecting PCBs in concentrations of less than 5 ppm in oil and 1 ppm or lower (by concentration) in water. Although they detected PCBs in ORNL air filters, they found that airborne PCBs at the Laboratory are well below the maximum permissible level.

Toxic Organics in Water

The quick response team also anticipates future problems for which it may have to be prepared. Says Stewart: "The Nuclear Division is not able to quickly identify trace toxic organics in water, such as glycols. We need inexpensive, rapid methods of analyzing water samples for organics in case of a chemical spill or leakage of hydraulic fluid."

An effort to develop such methods has been spearheaded by Mike Maskarinec, who has worked on analysis of organic chemicals and has recently been involved in the 1981 water sampling program at ORNL.

"This effort," he explained, "involved monitoring 11 individual outfalls around the plant from which water eventually winds up in the creeks. We looked for the 112 priority pollutants listed by EPA. These include PAHs, PCBs, pesticides, solvents, and other volatile compounds. In the samples we analyzed, we found chemicals in only part-per-billion and -trillion levels—well below what would be considered significant. The object of this sampling and analysis was to make sure that our final effluents do not exceed pollutant levels allowed by EPA in the discharge permits granted to ORNL."

Maskarinec is now adapting the methods used for routine water analysis to nonroutine, rapid response identification aimed at determining the organic content of spilled material and its source.

"Whenever ORNL has a fluid spill such as an antifreeze leak," Maskarinec says, "chemists have a difficult time characterizing the fluid and determining where it came from. It is easier to detect an oil spill because of its visible sheen; hydraulic fluid, on the other hand, is water soluble and not easily noticed unless it changes the water's color. Oil can be more easily identified because it has a unique chemical composition and because its manufacturer has data on its composition. Virtually no information on the composition of hydraulic fluids exists. And once they are spilled into waterways, many of their constituents are dissolved away."

Of all the organic compounds most likely to be spilled, the easiest to analyze are those having high vapor pressures at room temperature—the volatile organics. A technique that Maskarinec uses to analyze rapidly for volatile organics in water is the "purge and trap" method promulgated by the EPA. An inert gas is bubbled through water (purge), and the gas is run through a cartridge containing an absorbent (trap) consisting of charcoal, silica gel, and Tenax. The absorbent traps the volatile constituents, separating them from the water. The trap is then heated, causing the volatiles to be released so that they can be analyzed by gas chromatography.

Volatiles fall into the class of extractables—they can be extracted easily from water for chemical analysis. Other organic compounds having a high potential for being spilled cannot be readily extracted from water or analyzed directly in water by gas chromatography. These compounds are called intractables. They must be prepared for analysis by techniques that make the compounds extractable or identifiable. For example, ethylene glycol (standard antifreeze) is a water-soluble compound that must be chemically modified in water before it can be extracted and analyzed by gas chromatography. Other intractable compounds are amino phenols and acetic acid. Maskarinec and his colleagues are trying to develop methods for rapidly identifying intractable compounds in water.

A chief target for analysis is ethylene glycol. Explains Maskarinec: "Ethylene glycol is not toxic but its presence in water indicates that a hydraulic spill has occurred. Hydraulic fluids are an environmental problem because they contain additives such as anti-oxidants which are added to prevent corrosion in air conditioning systems. Unfortunately, these anti-oxidants also scavenge oxygen out of water in creeks and lakes, reducing dissolved oxygen content and sometimes causing fish kills."

To screen water samples for toxic organic compounds, Maskarinec and his associates are developing a total approach, or combination of methods. First, they plan to analyze the water by the purge and trap technique and by gas chromatography. If they want more information on the chemical composition of constituents separated out by GC, they can obtain it by mass spectrometry. For intractable compounds, they may tag the water with fluorescent chemicals that bind to intractables or chemically modify the intractables to make them extractable. If they suspect that the water contains halogens or nitrogen or nitrosamines, they might try specific detection techniques such as the Hall Electrical Conductivity Detector, which has great selectivity and sensitivity for these compounds.

"I hope ORNL never has any more spills of oil, hydraulic fluids, or other chemicals," says Maskarinec. "But if we do, we will soon have the capability of detecting the constituents of most any spill and where it comes from."

Stewart observes that the emergencies do not seem to go away when a capability for emergency response is available. "We may be a lightning rod that attracts problems," he says. Still, he enjoys the excitement of his job and the opportunity to interact with many people at the Laboratory and in various government agencies. Stewart is especially proud of and enthusiastic about the people who make the quick response program so successful—ORNL's analytical chemists on call. ornl

Aspirin and X Rays Cure Headaches of Asbestos Analysis

Two years ago, the EPA issued a ruling that requires builders to treat construction materials as if they contain asbestos, a suspected carcinogen and irritant to the human respiratory system.

Unless builders can prove that their construction materials contain less than 1% asbestos, they are required to take a number of costly measures to protect workers and the public, including sealing waste material in plastic bags, fencing off the construction area, and ensuring that the construction crew wears respirators and clothing that is frequently laundered. Occasionally, when parts of an old building at ORNL are being demolished for renovation, the construction manager needs to know as soon as possible whether the torn-out materials contain asbestos and whether precautions are necessary.

Now, a new technique developed at ORNL for both routine analysis and quick response permits accurate determination of asbestos content in construction materials, including microscopic amounts of 1% or less. Using aspirin and x rays, the technique promises to cure the headache of quantifying trace amounts of asbestos. Because it is more accurate than microscopic fiber counting and other methods, the EPA is considering adopting the ORNL technique as the recommended method.

Developed by Harris Dunn, Bob Sherman, and Joe Stewart of the Analytical Chemistry Division, the technique is being used to analyze EPA reference materials and samples of building materials from ORNL construction sites, such as wallboard, firebrick, cement, and ceiling and floor tiles. By screening out the materials that have less than 1%

Joe Stewart shows some samples of wallboard and acoustical ceiling tiles that have been found by x-ray diffractometry to contain 5% asbestos. Because of this result, workers tearing down a portion of the ORNL cafeteria from which these samples were taken had to take special precautions to protect themselves and the public. Stewart, who helped develop the asbestos measurement technique, is ORNL's emergency response coordinator for nonradioactive chemical spills and hazardous materials.

Harris Dunn works at an Apple II Plus computer with a bottle of aspirin on top. In the background is the x-ray diffractometer used for analyzing the asbestos content of construction samples from ORNL and EPA. The chart shows aspirin and asbestos peaks.

asbestos, the analytical chemists have saved ORNL the expense of taking unnecessary precautions.

Using the optical microscope and transmission electron microscopy, Dunn and Sherman can rapidly determine which building materials have a substantial amount of asbestos (as much as 25%) and which have near-zero quantities. Asbestos is no longer added to newer materials because a recent law forbids it. However, materials made before this law went into effect contain large amounts of asbestos, a magnesium silicate complex that had been routinely added to building materials to make them fibrous and resistant to fire and decomposition from heat.

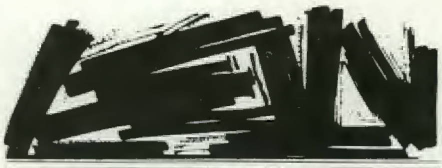
Those materials found to contain asbestos in the questionable range (say, 0.5 to 5%) are analyzed by the ORNL technique using x-ray diffractometry. The key to making this technique work is to mix about 0.3 g of aspirin with 1 g of the pulverized asbestos-containing sample and press it into a pellet about the size of a quarter. The pellet is placed in the x-ray diffractometer, which exposes the sample to x rays emitted by a copper target x-ray tube. X rays of a specific wavelength pass into a crystalline form of asbestos called chrysotile and are diffracted (forced to change direction, like light reflected from a mirror). The diffracted x rays are recorded as peaks on a chart, each representing the number of x-ray photons diffracted by a specific element or compound. The higher the peaks or accumulated counts, the more asbestos is present.

Why is aspirin needed for this analysis? The use of x-ray diffractometry alone resulted in peaks for asbestos that varied for different building samples, such as concrete and wallboard, even though each sample contained 1% asbestos. In such cases, Dunn knew an "internal standard" must be used to compare with the asbestos concentration. In checking different materials, Dunn found that common aspirin has a strong peak near a strong peak of chrysotile asbestos. He proposed that aspirin would make an excellent internal standard.

The idea worked well. The aspirin corrected for the other constituents of the building material that would have given misleading results about the actual asbestos content. Dunn, Sherman, and Stewart developed a "working curve" for known concentrations of asbestos and a constant amount of aspirin. Now, when they analyze an unknown sample, they can determine the asbestos content from the working curve by comparing ratios of x-ray peaks of asbestos and aspirin.

"Aspirin has the advantage of correcting for matrix effects," says Dunn. "Some building materials have mostly light elements (cellulose fibers), whereas others have heavier elements such as calcium and iron, which could absorb more of the absolute intensities of x-ray peaks. Because both aspirin and asbestos x-ray peaks are being absorbed by the same elements, the internal standard corrects for the difference in the densities of building materials. In other words, the ratio of the aspirin and asbestos x-ray peaks is unaffected by the presence of the other constituents."

So if you are getting nervous about the asbestos there might be in materials around you, relax, take two aspirin, and call Harris Dunn in the morning.—C.K.



BOOKS

Benjamin Thompson, Count Rumford, *by Sanborn C. Brown, MIT Press, Cambridge (1981), 361 pp., $9.95 (soft cover). Reviewed by R. N. Lyon, consultant, Energy Division.*

The next time you warm yourself in front of an open fireplace, think of Massachusetts-born Benjamin Thompson, Count Rumford of the Holy Roman Empire. He invented the principles by which modern fireplaces are designed. The next time you enjoy oven-roasted meat, think of Count Rumford. Before his time meat was always roasted over an open fire—Charles Lamb's "On Roast Pig" notwithstanding. In both cases, Rumford's idea, two hundred years ago, was to conserve fuel.

Everyone who learns more about Count Rumford than his famous "cannon-boring" experiments (in which cannon were not bored), is captivated by the paradoxes, adventures, and historical, scientific, technological, and social contributions of this brilliant, driven, insensitive, antidemocratic, social reforming, eccentric, military, handsome, self-aggrandizing, informally educated natural philosopher, inventor, and administrator. Several dozen authors have been captivated in that way, and have written biographies of Thompson, Rumford. But Sanborn Conner Brown has done it right.

The style of the book is light and nutritious. It is effortlessly readable, and when you are through you know much more, not just about Rumford, but about the sociology, politics, and scientific thinking of the period from the French and Indian wars in America to the early post-Napoleonic years in France. Starting in Woburn, Massachusetts, on March 26, 1753, Benjamin Thompson, Count Rumford's swath extends through America, England, Bavaria, Switzerland, Italy, and France. It ends in Auteuil, just outside of Paris, on August 21, 1814.

Two of Rumford's natural children were born to a mistress of Carl Theodor, Elector of Bavaria, to whom he was military advisor. One of Rumford's favorite feminine confidantes, and presumed occasional bedfellow, was Lady Palmerston. Lady P. often traveled with him, sometimes and sometimes not accompanied by Lord P., who appears to have approved of their relationship. Among Professor Brown's insights into the mores of court life is the following: "In July, Lady Palmerston wrote to ask if Rumford had yet had a chance to go to bed with the new Electrice. During the summer of 1796, Carl Theodor's queen had died, and he had almost immediately married a 19-year-old Austrian princess. Since he was over 70, it was generally assumed that he had been asking his friends for help in providing him with an heir."

According to Professor Brown, marriages in the upper social classes of Europe were almost always arranged for political and economic purposes, seldom for love or lust. The brides were often as young as 12 or 13, whereas the grooms were a decade or more older. As the husbands aged, they usually welcomed young men who could entertain their young wives and claimed any resulting children as their own.

Intense curiosity regarding natural phenomena and their practical applications seems to be the central thread on which the beads of Rumford's career and character are strung—from his early discussions with his young neighbor, Loammi Baldwin in Woburn, to the final visit in November 1813 of his former protege, Humphry Davy.

Although Thompson had been elected to the Royal Society of London at the age of 27 and had been knighted, somewhat reluctantly, by George III, it was in Bavaria that he was given the freedom, authority, and resources to carry out most of his military, social, engineering, and scientific ideas. His first assignment was to reorganize the Bavarian Army.

One of the several reasons for his success was his establishment of "military workhouses," in which he housed "tramps, beggars, vagrants, smugglers, and defrauders of the customs." It was in devising new methods of cooking, heating, and lighting for his workhouses that he developed many of his ideas for improving the recovery of heat from fires and for improving the illuminating lamps of the day. In connection with the latter, he developed and named the first "photometer," which he described in a paper before the Royal Society in 1793. By that time, the Elector had promoted him to Count Rumford of the Holy Roman Empire.

He discovered by accident that the process of oven roasting meat required much lower temperatures than he had anticipated. The oven he was experimenting with had originally been designed for drying potatoes, but Rumford was curious to know whether it could be used as a fuel-efficient way of roasting meat. He reports:

"It being late in the evening, and the cooking maids thinking, perhaps, that the meat would be as safe in the drying-machine as anywhere else, left it there all night. . .

In the morning. . . .they were much surprised to find it already cooked, and not merely eatable, but perfectly done, and most singularly well tasting."

Rumford's Essay IV was entitled "Of Chimney Fireplaces with Proposals for improving them to save fuel; to render Dwellinghouses more Comfortable and Salubrious, and effectually to prevent Chimnies from Smoking." Professor Brown states that in that essay Rumford "laid down all the principles of a properly designed, modern open fireplace . . ." The publicity attending his improvements led several cartoonists in England to publish anatomical depictions of the enjoyment of the "Rump ford." On the other hand, the adoption of the improvements throughout England and Europe made him a wealthy man.

Let us now consider one of the paradoxes of Rumford's life. Benjamin Thompson left America, and a wife and daughter in New Hampshire, in March 1776 at the age of 23. For the preceding year he had spied remarkably effectively for the British against the Colonial armies.

In early October 1781, Lt. Col. Thompson sailed from Cork for New York as commanding officer of the "King's American Dragoons," which he had organized in England, ostensibly from among the American Tory expatriots then in England. He landed in Charleston, South Carolina, where he and his dragoons (cavalry) stayed until March. Thompson did not sit idle while in Charleston, however. He galvanized the British troops and led a number of forays against the forces of Gen. Francis Marion, the "Swamp Fox"; these actions were successful enough to win Thompson a letter of commendation from Gen. Leslie in Charleston to Gen. Clinton.

On landing in New York, he and his dragoons were stationed in Huntington, Long Island. There he allowed his troops to inflict "vindictive oppression" on the local inhabitants. Finally, before leaving in February 1783, three months after the peace treaty had been signed, he ordered his troops to gather up and burn all the chestnut fence rails in the area "so that the populace would have neither fences nor firewood."

Sixteen years later, Rumford was asked to come to the United States and found the United States Military Academy at West Point. After first accepting, Rumford declined because of his commitments in the founding and development of the Royal Institution in Great Britain.

With that decision, he turned his back on military affairs and donated his military library, military papers, and models of cannon, field kitchens, ordnance-testing equipment, and other military inventions to West Point. His will left the remainder of his library to West Point as well.

Perhaps the most surprising paradox in Rumford's life was his marriage to Mme. Lavoisier, widow of Antoine Lavoisier, the famous French chemist. Lavoisier was the inventor of "caloric" as an "igneous fluid" to replace "phlogiston" after Joseph Priestly disclosed his discovery of oxygen during a visit to Lavoisier in 1774.

The irony of his marriage to Mme. Lavoisier was not lost on Rumford. Professor Brown quotes from a letter written to Lady Palmerston in February 1804:

"I think I shall live to drive caloric off the stage as M. Lavoisier . . . drove away Phlogiston. What a singular destiny for the wife of two Philosophers!"

Author Sanborn C. Brown, born in 1913, was for many years "a physicist and teacher" at MIT. He spent forty years collecting the documents and documented information for this book. The fact that he has already published *Collected Works of Count Rumford* (Cambridge, Mass: Harvard University Press, 1969) frees him from detailed descriptions of all of Rumford's work in natural philosophy. Yet he includes sufficient sketches, quotations, descriptions, and comment to satisfy most readers. He describes the "cannon-boring" experiments in considerable detail, and, obviously, coming from a student of history such as Professor Brown, the discussion is particularly important.

"I can conceive of no delight like that of detecting and calling forth into action the hidden powers of nature!...Of finding the Elements in chains and delivering them over, the willing slaves of Man!" wrote Rumford in one of his letters.

Neither Rumford's estranged wife nor his daughter was immediately aware of his death on August 21, 1814, or of his burial three days later. His daughter believed that it was a trick and, as evidence of the influence her father had over her, became convinced that she had seen him twice in England after his death. After all, as she said years later, "He was a strange man."

I recommend this book to scientists, engineers, and historians, but most of all, I recommend this book to all people who enjoy a well-written account of a fascinating man. ornl

Strip mining contributed to the severe flooding that struck many Appalachian towns in April and October of 1977. Among the hardest hit by the April flood was Pineville, Kentucky, where disaster-aid grants totalled $20 million. (Photograph courtesy Louisville Courier-Journal.)

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Mining Land Reclamation

ORNL and the abandoned coal mines

By JON JEFFERSON

A small river, the Tug Fork, flows through the heart of Appalachia's coal country. Springing from hillsides and hollows in the southern tip of West Virginia and the western arm of Virginia, it angles northwest, forming the border between Kentucky and West Virginia. At Louisa, Kentucky, it joins the Levisa Fork to become the Big Sandy River, a tributary of the Ohio. The two states on either side of the Tug Fork and Big Sandy contribute about one-third of the nation's coal, roughly $7 billion worth in 1980.

A century ago, the Tug Valley was the battleground in one of Appalachia's bloodiest feuds, the clan warfare between the Hatfields of West Virginia and the McCoys of Kentucky, a feud said to have claimed at least sixty-five lives.

Despite the violent past of the land surrounding it, however, the Tug Fork itself is usually calm—dirty, but calm. In April 1977, though, two days of steady rain forced the river 17 m (57 ft) above its normal level, out of its banks, over the floodwalls, and into the adjacent towns. The flooding left thousands of homes and businesses destroyed or damaged; the U.S. Army Corps of Engineers estimated the total damage at $200 million. When the Tug Fork flooded again that October, some people hadn't yet recovered from the mud and debris of April.

Although heavy rains were the obvious cause of the flooding by the

Tipples dump (or "tip") coal from mine cars into trucks or trains. Abandoned tipples, such as this one, pose hazards to people who venture onto them or into the shafts they top.

Tug Fork and other Appalachian rivers, another factor magnified the effect of the rains: strip mining has cleared considerable areas of trees and other vegetation, which normally slow the runoff of water and protect against flash flooding. That problem was compounded by the fact that sediment and debris from strip mining had clogged streams and rivers, lessening their capacity to handle the excess runoff.

On the West Virginia side of the Tug Fork, problems linked to strip mining are generally less common than those linked to deep mining. The most serious of these is subsidence, a settling or opening of the earth, caused by the collapse of underground mine chambers. Subsidence can swallow buildings, make farmland unplowable, even crack whole mountains. Cancerlike, it eats away at property year after year, long after underground mining has stopped.

Other problems are common to both strip mining and underground mining. One is the presence of "gob piles," heaps of carbon-containing debris removed from the ground along with the coal. Gob piles often contain enough coal to burn if ignited spontaneously or by other means; once ignited, they are difficult to extinguish. As they burn, they emit noxious fumes and become potential death traps to people who venture onto the thin crust covering their interior fires. Some of the piles loom above houses and streets, grim reminders of an enormous pile that slid down a mountainside in Wales in 1966, destroying an elementary school and killing more than 200 of the children inside.

To regions like the Tug Valley, mining is both a blessing and a curse. Mining brings wages into the generally depressed mountain economies, but it also brings problems. Some are the result of active mines; most, however, are the legacy of inactive mines, mines abandoned before the days of proper reclamation. A few of these problems will fester for years or decades with no prospect of improvement.

Now, though, there is hope for these sites, offered by a reclamation program of the Office of Surface Mining, a part of the Department of the Interior. The OSM program includes a multimillion-dollar ORNL project that's coordinating a nationwide survey of the problems posed by abandoned mining sites.

Taxation to Remedy Past Error

The OSM program began about four years ago. In August 1977, four months after the Tug Fork's spring floods and two months before the fall ones, President Carter signed into law the Federal Surface Mining Control and Reclamation Act (PL 95-87). Part of the act requires, as a minimum, that operators of mines active on or since August 3, 1977, restore the mined lands to their original, premining topography and set them on the road to environmental stability and usefulness, either for vegetation or for other uses. Another important part applies to past mining and provides money for reclaiming sites where mining had stopped before the enactment of the new law.

The reclamation is being financed by fees assessed from active mines: 35¢/ton for surface-mined coal, 15¢/ton for underground coal, and 10¢/ton for lignite ("brown coal"). Over the 15-year lifetime of the program, these fees are expected to yield $3 billion to $4 billion for reclamation.

Half the money is to be returned directly to states (and Indian nations) whose regulatory and reclamation plans meet OSM's approval. Up to another 20% is made available by the Secretary of the Interior for the Department of Agriculture's use in restoring the productivity of rural agricultural lands damaged by past mining. The remainder is for OSM to use for emergency health- or safety-related actions, for helping small mining companies trying to meet the technical demands of permit applications under the act's regulations, or for special problems. Such special problems might include those too costly for a single state to

This mountaintop in Mingo Co., West Virginia, is shrouded in fumes issuing from far underground—the result of a mine explosion two decades ago. Don Bohrman, formerly of the AML Inventory, finds the air here high enough in CO to cause light-headedness.

correct or those along state borders, where the responsibility for action can not be clearly assigned.

When most people hear of reclamation, they think first of correcting general environmental problems, such as water pollution or erosion. The main focus of reclamation in the act, however, is on people-related problems: its first priority is "the protection of public health, safety, general welfare and property from extreme danger of adverse effects of coal mining practices." In emergencies, OSM can act immediately to accomplish that goal, even in states not yet meeting OSM regulatory and reclamation standards.

Lower-priority concerns are the ones more generally associated with degraded natural resources: water quality, reforestation, recreation resources, aesthetics, and agricultural productivity. These are lower in the priority scheme because funds are limited. The amount of money expected for reclamation during the program's 15-year lifetime—several billion dollars—is dwarfed by the estimated cost of correcting all the problems: a staggering $30 billion, according to a 1978 Bureau of Mines estimate. In severely affected states such as Kentucky and West Virginia, then, only the highest-priority problems are likely to be corrected.

Inventory AML

Translating the program's objectives and money into practical results—"getting the bulldozers rolling," as some of the program's members call it—requires data on which to base plans, cost estimates, actions, and evaluations. Such data should indicate where reclamation is needed, what problems need the earliest attention, and what kinds and sizes of projects should be attempted. That's where the ORNL project, the Abandoned Mine Lands (AML) Inventory, comes into play.

The AML Inventory is a nationwide survey of past mining sites and the problems left behind. The project has two phases: the design of the inventory and the collection and processing of the data. The responsibility for actually gathering the data rests with the states, since they will be the main users of the information and will receive the most benefit from the reclamation program. The Laboratory's contribution is the design of the data-collection and -analysis systems, which ensure that the information from the states is adequate, consistent, and in a form useful for subsequent decision making.

Inventory Design

Designing the inventory has been an interdisciplinary team effort from the beginning. From ORNL's Energy Division, geographer Bob Honea serves as overall project officer; landscape architect Carl

Underground mining brings to the surface much material that, although not marketable as coal, often contains enough carbon to burn. This smouldering waste pile in McDowell Co., West Virginia, is aptly named "the fires of hell."

Petrich is a liaison between ORNL's work and OSM, the states, and other participants; Dick Rush contributes technical expertise to the inventory's design and implementation and also handles the project's administration and sizable budget; Al Voelker acts as troubleshooter of technical problems and analyzes the inventory data. From the Computer Sciences Division of Union Carbide Corporation's Nuclear Division, group leader Richard Durfee managed the first phase of the inventory and has overseen the development of the computer systems for the data-collection phase; another information scientist, Bob Edwards, has had primary responsibility for the design and testing of the inventory; and systems analyst Don Wilson oversees the important processes of reviewing and computerizing the data.

The AML Inventory is not strictly an ORNL project, though. The Tennessee Valley Authority has worked closely with ORNL in establishing the inventory. TVA's work represents more than a quarter of the project's funding from OSM. TVA has supplied both management and research personnel to work on the project. Paul Baxter of TVA serves as the overall project manager of the data-collection phase. Another TVA manager, King Taft, is in charge of state and regional activities. Major subcontractors on the project are Lockheed's Oak Ridge Engineering Center, a subsidiary of Lockheed Missiles and Space Company; Bob Peplies and research assistants from the Geography Research House at East Tennessee State University; and staff and research assistants from the University of Tennessee.

In addition to these core members of the project's planning team, OSM staff participated in the early design meetings, along with state and federal personnel experienced in handling AML problems. The diversity of the planning team is impressive: all told, it included foresters, library scientists, computer scientists, systems analysts, landscape architects, geographers, chemists, physicists, natural-resource specialists, geologists, and mining engineers.

One important task for the planners was the development of a method that would ensure that all areas affected by AML problems would be included in the survey. The problems generally correspond to the distribution of coal resources and are especially severe where topography and rainfall are extreme. In the eastern United States, most of them are related geographically to watersheds. Accordingly, watersheds are the basis for planning and surveys in eastern states. Small, related watersheds are grouped to form areas of about 50 to 250 km^2 (roughly 20 to 100 sq miles). In the drier West, however, where water-related impacts are less likely, the states have generally used U.S. Geologic Survey quadrangles as planning units. The planning units are further divided into problem areas, which are the basis of the inventory itself, the real focus of the project.

The inventory, developed concurrently with the mapping procedure just described, evolved considerably between its initial conception and its final form. At first glance, aerial surveys and other forms of remote sensing seemed the ideal way to catalog AML problems. However, a closer look at the capabilities and costs of remote sensing suggested that the technique would be too expensive and would do little to meet the stated goals for reclamation (i.e., primary focus on the fairly localized impacts of the mine-related problems). Remote sensing, as its name suggests, was too far removed. Designers also rejected the idea of detailed engineering studies and models, which would likewise be expensive and, in some cases (e.g., models for predicting subsidence or landslides), would yield little reliable information on which to base corrective actions. Moreover, such studies were not really needed for compliance with

This road was built on mining waste piled alongside a creek. The road collapsed when the creek washed away the base of the pile.

Subsidence, caused by the collapse of underground mine chambers, can be dramatic. This garage floor—and the car parked on it—have been swallowed by a 10-m-deep hole. A utility company's cherry picker, or bucket truck, provides a better look at the hole.

the act, which requires only that states locate AML problems, rank them by priority, and estimate the costs for abatement or reclamation. As a result, the focus of the inventory became field data, which promised to be both cheaper and more closely linked with AML reclamation goals.

With the focus on field data, another important consideration in the survey design was the way in which the data would actually be collected. Field workers would come from diverse backgrounds, and many would be relatively unfamiliar with the coal industry. For this reason, and to ensure completeness and consistency, state surveyors and administrators received extensive training on both the nature of the problems they would be asked to quantify and techniques for obtaining the data.

As the survey evolved, an important addition was the provision for qualitative data to supplement the quantitative. Besides straightforward facts about physical conditions (e.g., the size of an abandoned structure), the survey seeks local residents' perceptions of the problems the conditions pose ("We're trying to get that structure torn down because kids play in it all the time, and it really scares me they'll get hurt"). Survey designer Bob Edwards says that this feature reflects the reclamation program's focus on people and how they're affected by the problem. And despite what some people think, Edwards adds that if it's interpreted properly, such information doesn't make the survey less accurate. "It's very exact, very rigorous," he stresses. "You can study the effects of energy extraction as precisely as you can measure the molar efficiency of a synfuels plant. It's a shame there's been so little recognition of the precision with which we can measure the effects of our energy policies and practices."

A preliminary test of the survey mechanism was conducted in 1979 along the South Fork of the Kentucky River, a heavily mined area with many AML problems. A year later, a revised version was tested on a larger scale in the Tug Valley, where the problems are more severe.

These preliminary tests led to improvements in the survey method and in the surveyors' training. "When we began," explains Bob Honea, "we were interested simply in providing information so others could rank-order problems. But it soon became apparent that doing that wouldn't necessarily allow for a variety of approaches to decision making and for the next step, implementing specific projects. We had to consider how the data would eventually be used." Accordingly, changes were made to ensure that the data would be consistent despite the diversity of field workers' backgrounds and experiences and the variability of impacts. Other changes allow states to expand the form and thereby tailor it to their special interests, a feature that reflects the AML program's emphasis on state action.

Besides suggesting refinements, the tests also confirmed the feasibility of the data-collection method. Most of the surveyors in these tests were Bob Peplies' geography graduate students from East Tennessee State. Although the students had little prior training or experience in evaluating these kinds of problems, a check of their work showed that their professional training and backgrounds in survey procedures

Unreclaimed strip mines, such as this one in Clay Co., Kentucky, allow rapid erosion and pollute surface water.

Many gob-pile fires are started by the dumping and burning of trash. ORNL's Al Voelker, front, and Bob Peplies, a professor of geography at East Tennessee State University, inspect a burning, trash-laden pile in McDowell Co., West Virginia.

gave them a good basis for describing the problems and identifying suitable remedial actions. Thus the tests demonstrated that even with relatively untrained field workers, the states could gather reliable data on their AML problems. The tests also gave a rough idea of how much the states' field surveys would cost.

The states began surveying in January 1980, and the data began coming in six months later. Once an area has been surveyed, the state sends the completed data sheets to ORNL. Surveys indicating extremely serious problems are flagged for OSM's immediate attention. Already several projects for correcting such problems have been completed. In West Virginia, for example, a vandalized shed was found to be filled with rotting explosives and blasting caps. State officials removed and safely disposed of the material within several days of its discovery. In Kentucky, a tougher emergency problem took several months and more than $100,000 to correct: a short stretch of state roadway, built over coal refuse that subsequently caught fire, was collapsing into the voids left by the burning. Highway crews working on a major project nearby extinguished the fire and rebuilt the road.

The completed surveys become part of the National AML Inventory. The forms and maps are kept on microfiche and an abstract is stored in the computer-based management-information system, which can produce a variety of graphs and tables for routine or special analyses. As states complete their inventories, a duplicate of ORNL's data base for each state is sent to OSM headquarters in Washington, D.C. In addition, each participating state has a manual or computerized record of its data, which is geared to its own needs and programs.

The inventory's uses are not limited to reclamation. Already, for example, coal companies have requested information on the location of refuse piles. Some of the piles contain more than 50% coal, and with today's more efficient extraction techniques and higher coal prices, they could profitably be reprocessed.

But the primary mission of the inventory is, of course, the correction of the serious problems that have affected people and their communities. According to Edwards, already about a hundred of those problems are being tackled by reclamation projects and another seven hundred projects are in the planning stage. Carl Petrich estimates that by late summer of 1982, when all the surveys should be finished, about 7000 separate problem areas will have been surveyed, in about three dozen states and on four Indian reservations. Within those areas, perhaps a thousand problems that endanger the public's health, safety, or general welfare will have been identified and targeted for the highest-priority reclamation work.

Of course, many AML problems will remain unsolved. For that matter, even a complete inventory of all AML problems will probably never be possible: they are too numerous and change continually. But with ORNL's help, the OSM reclamation program is already getting the bulldozers rolling in many areas that, up to now, have mainly seen equipment guided by a far different purpose. ornl

information meeting highlights

Physics, Nov. 11–12, 1981

Holifield Accelerator in Action

The 25-MV tandem electrostatic accelerator of the Holifield Heavy Ion Research Facility has not yet operated at its full design potential, but its ion beams were sufficiently powerful for researchers to begin experiments. In fact, the accelerator broke three world records by operating with acceleration tubes at 22 MV, by maintaining steady operation with a beam at 20 MV, and by providing beams for scheduled experiments at 19 MV.

Because of problems such as spark-induced deconditioning, terminal potential with acceleration tubes was limited to 22 MV. In mid-November, experiments were halted so that the National Electrostatics Corporation, which constructed the tandem accelerator, could work on bringing the accelerator up to its design potential of 25 MV.

The first experiments completed on the tandem accelerator in 1981 were elastic and inelastic scattering studies of nickel ions—nuclei partially stripped of electrons. By colliding beams of ^{60}Ni ions with thin foil targets of ^{60}Ni, ^{58}Ni, and ^{56}Fe in three different experiments, Karl Erb and a team of eight other physicists in the Physics Division ascertained the probability that the colliding ions would scatter elastically (bounce off each other with no transfer of energy, like two billiard balls striking each other and bouncing apart at a 90° angle). Of particular interest to the physicists was the probability of inelastic scattering (as when one ball partially absorbs the impact of another ball) and the more complex process of fusion (two balls sticking together).

Erb and his colleagues found that the probability of inelastic scattering is huge—much larger than had been anticipated. Much lower was the probability of fusion at or near the Coulomb barrier—a barrier caused by the repelling electrostatic force between nuclei, which is overcome by accelerating particles to high enough energies. According to Erb, this finding was a surprise; most physicists who have studied collisions of lighter-mass nuclei with lower-energy accelerators have assumed from previous findings that the probability of fusion (fusion cross section) would be much larger at or near the Coulomb barrier.

In his status report on the 25-MV tandem accelerator at the Physics Division information meeting, Charles Jones said that experiments were done in 1981 with beams of boron, carbon, fluorine, magnesium, nickel, oxygen, silicon, sulfur, and titanium ions. He attributed the success of these early experiments, in part, to a versatile, prolific source of negative ions called the Aarhus source, which was developed at ORNL by Gerald Alton. Said Jones: "The yield of negative magnesium ions from the Aarhus source is ten times that of the typical Middleton-type sputter source."

In the tandem electrostatic accelerator, negative ions are accelerated up the 20.3-m-high column structure by the large voltage difference between ground potential and the positive terminal at the top; these ions are stripped of their electrons and converted to positive ions in the positive terminal, which repels and forces them to be re-accelerated back to ground potential.

As he retraced the history of the construction and testing of the tandem accelerator, Jones noted that the accelerator had passed a number of tests. Although problems relating to sparks have prevented the accelerator from reaching its full electrostatic potential, Jones is optimistic that the national users' facility will be in working order in 1982 for ORNL researchers (3000 hours is planned) and a fraction of the 400 users from other laboratories and universities.

Spin Spectrometer: Initial Results

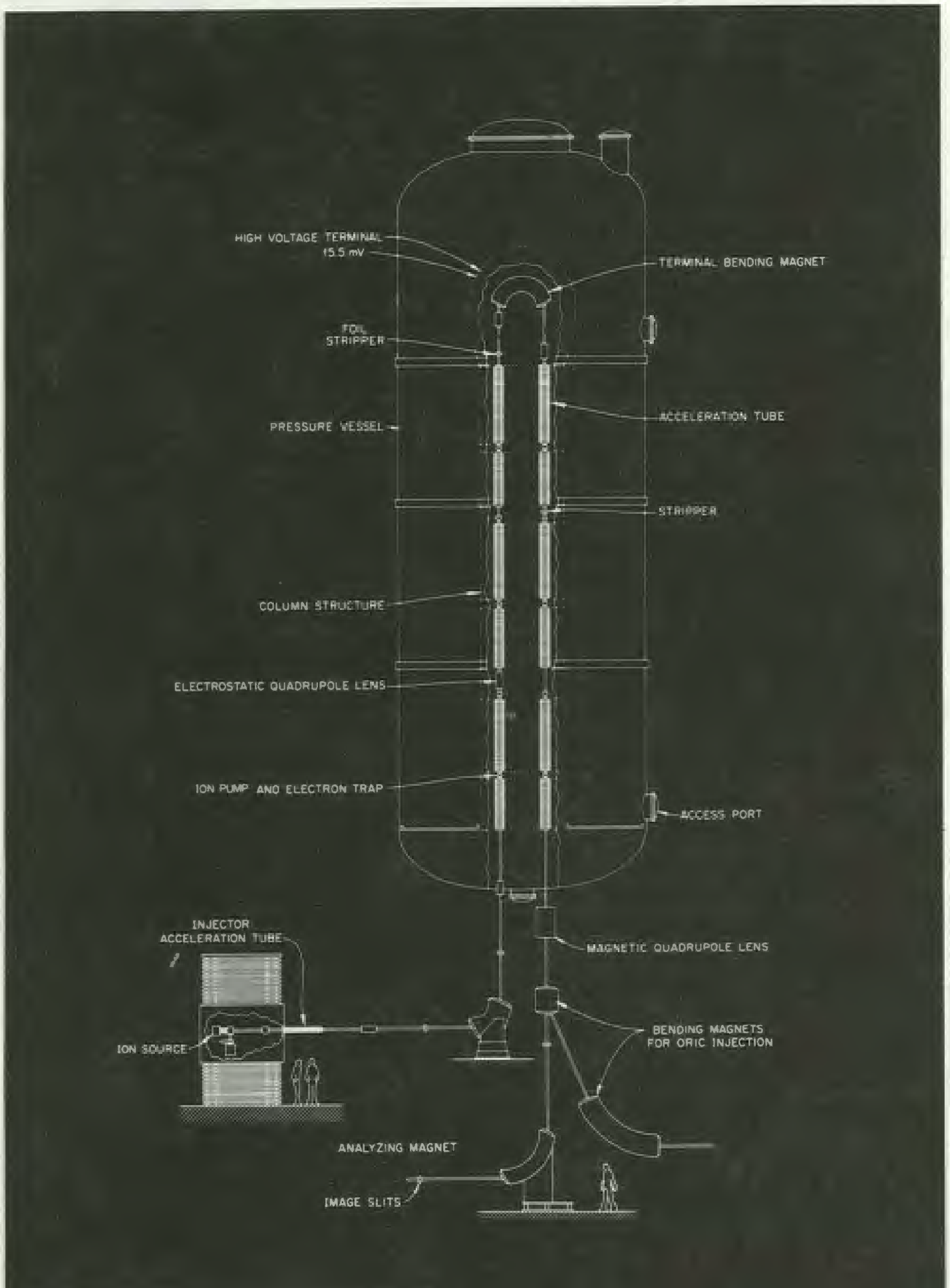
The Spin Spectrometer, sometimes called the crystal ball of the Holifield Heavy Ion Research Facility, is an array of 72 gamma-ray detectors which surrounds a target material being bombarded by heavy ions from the tandem accelerator or the Oak Ridge Isochronous Cyclotron. By counting and measuring the energies and directional distribution of all the gamma rays emitted by the excited nuclei as they settle down to ground state, the Spin Spectrometer provides information on the excitation energy and spin of the distorted nuclei formed by the fusion of target nuclei with heavy-ion projectiles. From this information, the altered structure and shape of these rapidly spinning nuclei can be determined.

The first experiments conducted on the spin spectrometer since its installation in April 1980 have yielded results on populations of entry states (states where gamma decay predominates) and Yrast states (states in which nuclei possess the minimum amount of excitation energy required for a given spin) in rare-earth residues resulting from decay of fused nuclei. Jim Beene, Mel Halbert, Dave Hensley, and several other researchers (including Demetrios Sarantites of Washington University, who was the prime mover of the Spin Spectrometer Project) bombarded ^{146}Nd nuclei with a ^{20}Ne beam from ORIC. Using 69 sodium iodide detectors in the spin spectrometer, they recorded data on the gamma rays emitted by the rapidly spinning ytterbium nuclei formed by the fusion of neon with neodymium.

To identify the products of the reaction as the fused nuclei cool down and decay into rare-earth residues, the team of scientists used a single lithium-drifted germanium detector in place of one of the sodium iodide detectors inside the crystal ball for accurate measurements of the energies of gamma rays. Neutrons, emitted before the gamma rays, carry away most of the excess energy of the excited nuclei. The neutrons could be distinguished from gamma rays by time-of-flight methods because neutrons travel more slowly. Beene and his colleagues found that spin states of the fused neon-neodymium nuclei up to the highest that can be sustained without fission occurring were achieved.

"As excitation energy and spin increase," Beene said, "the ytterbium nuclei formed from fusion of neon and neodymium tend to change shape." According to the liquid drop model of the nucleus, this shape change is from an axially symmetric, slightly prolate spheroid (football shaped) at low spins to a more complex (perhaps triaxial, i.e., with no axis of symmetry) and much more stretched out (superdeformed) shape at high spins.

The spin spectrometer has now been used with beams from the 25-MV tandem accelerator to study structure effects over a range of excitation energies and spins in fused nuclear species. In collaborative experiments with the Niels Bohr Institute in Denmark, 50 different targets were bombarded with a beam of energetic ^{50}Ti ions. Several charged-particle detectors were placed in the crystal ball to permit detection of protons, alpha particles (helium nuclei), and fission fragments cast off by excited nuclei as they reach higher spin states. "Enhanced alpha emission relative to fission," says Beene, "could be a signature of superdeformation at very high spin."



Cutaway of HHIRF, showing path of ion beam.

Do Light Nuclei Orbit?

Imagine a dance hall where the majority of the couples are dancing the foxtrot in a close embrace and appear to have merged into single bodies. Scattered among them are a few couples doing the jitterbug, whirling around as they hold hands, and then separating to dance by themselves. Such a dance scene has an analogy in heavy-ion physics.

When two light nuclei such as carbon and nitrogen collide at low and medium energies, the probability is high that their nuclei will fuse into a single distorted nucleus called a mononuclear complex, or compound nucleus. In collisions of heavier ions such as argon and lead, however, another important process that falls short of fusion has been observed. This process, called orbiting, occurs when two ions approach each other, form a dinuclear complex, and revolve very briefly around each other in a forward motion before flying apart.

Could orbiting be equally or even more significant for light nuclei (heavier than helium but lighter than lead) in higher-energy collisions? To find out, Dan Shapira, Karl Erb, Y.-d Chan, J. L. C. Ford, Jorge Gomez del Campo, and R. W. Novotny of the Physics Division bombarded light nuclear targets with light ions in the ORIC and in an accelerator at Brookhaven National Laboratory. They found clear evidence for orbiting of nuclear systems in collisions of silicon with carbon, neon with carbon, and aluminum with oxygen.

Their evidence is based on the measured energy and angle of emission of fragments of the bombarded nuclei. By measuring the excitation energies of the fragments and by analyzing the details of the backward-angle scattering, the physicists deduced that orbiting not only occurs but lasts much longer in collisions of light nuclei than it does in collisions of heavier nuclei. They also found that as ion beams are increased in energy, orbiting becomes more pronounced, just as when the tempo of dance music picks up, the predominant dance pattern may change from the fox-trot to the jitterbug. Because the orbiting lifetime is longer and the probability of orbiting rises, physicists are intrigued by the possibility that orbiting may become dominant in light nuclear systems as the energy of collisions increases even more.

Shapira and his colleagues plan to continue their orbiting experiments at the Holifield Heavy Ion Research Facility, where accelerating voltages are as high as 20 MV, 6 MV higher than that available at the Brookhaven accelerator. There's no place like home.

Far-Infrared Diagnostics for Fusion Plasmas

To understand how well a tokamak is working, fusion researchers need to know the density and shape of the plasma, the hot ionized gas that fuels the doughnut-shaped device. This information tells researchers about plasma stability, pressure, and impurities, all of which affect plasma confinement. Unless the plasma is successfully confined by magnetic fields, it loses its energy to the wall before sufficient fusion reactions occur to provide more energy than was required to contain and ignite the plasma. The goal of this research is to design tokamak reactors that are economic heat sources for making steam to generate electricity.

A new diagnostic system that gives information on plasma density and shape has been developed and successfully demonstrated for 3000 hours on the Impurity Study Experiment (ISX-B) device by Don Hutchinson, P. A. Staats, Ken Vander Sluis, and C. H. Ma of the Physics Division. The system consists of two formic acid lasers (optically pumped by a carbon dioxide laser) and a polarimeter, which measures the polarization of the laser light in plasmas. The formic acid lasers are submillimeter lasers—the wavelength of concentrated light produced by these systems is a fraction of a millimeter. Because this wavelength in the far infrared region is shorter than that of microwaves, the system is superior to the conventionally used microwave diagnostic system in that it does not fail to work when plasma density or plasma turbulence is high. In fact, the new system works so well that a Princeton University group is developing a similar diagnostics system for the Tokamak Fusion Test Reactor in Princeton, New Jersey.

The laser system pumps beams of light of two slightly different wavelengths through and around the plasma and measures the differences in speeds of the beams. The change in speed of the light beams provides information on electron density, a parameter related to plasma density.

At the same time, the new diagnostic system measures the Faraday rotation of the laser light as it penetrates the plasma. Discovered by the English scientist Michael Faraday in the 1880s, Faraday rotation is the rotation of the electric field of a light beam as it passes through a magnetically active medium such as plasma. ORNL physicists were the first to make multichannel Faraday rotation measurements in tokamak plasmas. From these measurements, they have determined changes in the profile of the plasma current, which provide information on changes in the plasma shape.

The Fusion Energy Division shut down ISX-B in November 1981 for improvements, so Hutchinson, Staats, Vander Sluis, and Ma have been able to devote more time to developing a methyl iodide laser system to substitute for the formic acid lasers when ISX-B is reactivated in 1982. The methyl iodide system is believed to be a better diagnostic tool than its formic acid counterpart because its slightly longer wavelength is not absorbed by air, its gas is more stable, and it offers increased sensitivity in plasma measurements. The ORNL physicists are also working with Tom Price of the University of Texas to develop an advanced plasma diagnostics system for the tokamak in Austin.

Metals and Ceramics, Oct. 21–22, 1981

Metallic Glass Defects

A new class of materials of increasing interest to researchers is the amorphous alloys, also known as metallic glasses. These noncrystalline materials have several highly desirable properties such as ductility—they stretch and bend easily without breaking. This ductility is based on defects, the nature of which is not understood. If the nature and structure of defects in amorphous solids were known, this information could be applied to the preparation of materials with desirable, well-defined properties.

Because conventional diffraction techniques used to reveal defects in crystalline materials provide limited information on the amorphous state, new experimental methods of probing the structure are needed. One method that has been tried successfully as a defects probe is the measurement of superconducting critical current density (J_c) in an amorphous alloy of molybdenum, ruthenium, and boron. This method has been carried out by Carl Koch, Jim Scarbrough, and Don Kroeger of the M&C Division. The success of the method stems from the fact that defects believed to be responsible for mechanical deformation and atomic transport also apparently influence certain magnetic and electrical properties in the host material. One such property is fluxoid pinning in a superconductor which, in turn, determines J_c.

In a superconductor, the magnetic field forced into the material by a current is concentrated in discrete filaments. This concentration of quantized lines of magnetic flux, or fluxoids, is pinned in regions where defects are introduced into the material. Without fluxoid pinning, the fluxoids are free to move, generate heat, and destroy superconductivity. Because fluxoid pinning controls J_c, J_c may increase by 3 to 6 orders of magnitude in defective crystals. Values of J_c in amorphous materials, however, are quite low, probably because of the absence of such crystalline defects as grain boundaries, dislocations, and precipitates.

Nevertheless, because J_c is a structure-sensitive measurement technique, Koch and associates thought that the size of defects responsible for fluxoid pinning in the amorphous molybdenum-ruthenium-boron alloy could be estimated by measuring changes in J_c in the alloy after it was modified by such thermo-mechanical processes as cold rolling and annealing. Following a series of experiments, they found that J_c decreased in the alloy after it was subjected to cold rolling or heat treatment. Says Koch: "Inhomogeneous deformation and annealing must degrade J_c by reducing the number density and distribution of these defects, or strain fields."

These J_c results plus additional information from small-angle x-ray scattering and transmission electron microscopy led to the conclusion that defects in the form of strain fields 10 to 20 nm in extent are responsible for the fluxoid pinning in the amorphous alloy as originally cast.

"Our results, which indicate that the defects are strain fields in the as-cast alloy, are consistent with calculations made by computer models," says Koch. "This is encouraging and supports our contention that J_c is a sensitive probe of defects in amorphous structures."

Better Weld Metals for Breeders

Metals used to weld stainless steel components for the breeder reactor program are more prone to rupture in shorter times and at lower strains than the austenitic steels they join in high-temperature vessels. Consequently, reactor designers must take into account the inferior properties of typical weld metals in high-temperature designs. Some research metallurgists, therefore, have sought to increase the creep resistance (the ability to resist a slow change in dimensions from prolonged exposure to high temperatures and stresses) and creep ductility of weld metals.

Now, Dave Edmonds, Ed Bolling, and Stan David of the M&C Division have developed stainless steel welding materials that possess not only increased creep strength but also improved ductility. They have found that controlled additions of titanium, boron, and phosphorus to 308, 316, and 16-8-2 stainless steels result in superior weld metals which they call CRE (Controlled Residual Element) materials.

During the past year, the M&C researchers completed testing of several large commercial heats of CRE weld metals, thus making significant progress toward commercializing these materials. They plan to obtain additional larger heats of CRE weld metals with the goal of including these materials in the American Society of Mechanical Engineers' Boiler and Pressure Vessel Code. Says Edmonds of the CRE weld metals: "Use of these materials will provide an additional safety margin in terms of creep strain and will allow for higher stress conditions, if the present weldment stress-reduction tables are accepted into the Code."

Toughening Ceramics

Two seed-money projects in the M&C Division have made progress in improving the properties of ceramics (i.e., products of firing nonmetallic minerals at high temperatures). For most of us, mention of ceramics conjures up images of earthenware, porcelain, glass, brick, and enamels; materials scientists in energy research, however, tend to think of ceramics as materials such as alumina, silicon carbide, and titanium diboride, which exhibit hardness and strength at extremely high temperatures.

Like all materials, ceramics have limitations. For example, ceramics have a low resistance to tensile stresses—that is, they tend to break when a crack begins because of their inability to absorb strain energy at the crack tip by deforming as metals do. Some researchers, therefore, have directed their efforts toward modifying ceramic materials to improve their fracture toughness.

In the M&C Division, Paul Becher and Vic Tennery have toughened alumina (Al_2O_3) by dispersing zirconia (ZrO_2) particles in the polycrystalline matrix. By using sol-gel chemistry developed in the Chemical Technology Division, they made alumina-zirconia composites that are substantially more resistant to fracture—that is, the fracture toughness increased 200 to 300%. This increased toughness results from a stress-induced phase change in the ZrO_2 particles. Tests showed that these composites resisted the rapid growth of cracks and possessed tensile breaking strengths of well over 100,000 psi. In addition to having high fracture strengths and increased fracture toughness, alumina-zirconia composites also are resistant to thermal shock. The researchers now plan to try hafnia (HfO_2) in place of zirconia because the increase in toughness due to the presence of hafnia particles may permit use of the ceramic material at even higher temperatures (more than 1000°C).

In an effort to improve the surface properties of ceramics, Carl McHargue of the M&C Division and Bill Appleton of the Solid State Division have experimented with ion implantation, which in the past has been reserved for surface modifications in metals and semiconductors. Using an accelerator to drive ions into ceramic samples, they explored the effects of bombarding alumina with beams of chromium, iron, nickel, titanium, and zirconium. They also studied the effects of implanting titanium diboride with nickel ions and implanting silicon carbide with chromium and zirconium ions.

As a result of ion implantation, McHargue and Appleton found that hardness increased in alumina and titanium diboride by 20 to 70%, and wear resistance and fracture toughness increased in alumina by 25 to 30% and by 15 to 50%, respectively. The interaction of the randomly distributed implanted atoms with the point defects induced in the surfaces by ion implantation (radiation damage) is believed to be responsible for these improved properties.

Ion implantation in silicon carbide, however, reduced the strength of the ceramic material. It was found that the crystalline structure of the surface was rendered amorphous by implantation, probably because silicon carbide is covalently bonded rather than ionically bonded like alumina and titanium diboride.

Health and Safety Research Oct. 7–8, 1981

Health Impact Codes

Suppose a farmer in the year 2020 decides to dig a well for irrigation and to plant food crops on land that, unbeknownst to him, was once a site for shallow burial of radioactive wastes. Is it possible to predict the health effects of these actions on the farmer, his family, and the consumers of the vegetables he grows? The answer is yes.

If you call up a new ORNL computer program on an IBM-360 terminal and enter certain data such as the radionuclide contents, soil permeability, and climatic conditions of the burial site, you will receive information on the probability that the farmer, his family, and consumers of his vegetables will suffer adverse health effects from their exposure to radioactivity in food or at the site.

The computer program that generates the answer is called PRESTO (Predictions of Radiation Effects from Shallow Trench Operations). This generic model assesses radionuclide transport, normal and accidental releases, ensuing exposure, and health impacts to a static local population for a 1000-year period following the end of burial operations. Health impacts are tabulated in terms of percentages of deaths, cancers, and genetic effects expected from the predicted exposure level.

PRESTO is one of a series of computer programs and data bases developed in ORNL's Health and Safety Research Division (HASRD) to assess health impacts of airborne releases of radionuclides. Another computer code, AIRDOS-EPA, can evaluate the health impacts of normal and accidental releases of radioactivity into the atmosphere, as in a hypothetical case in which radioactive material stored in a tank is suddenly spilled at a nuclear facility.

The AIRDOS computer code was used to estimate radiation doses to people from noble gas releases during the March 28, 1979, accident at Three Mile Island nuclear power plant. ORNL prepared calculations in response to a request from the Task Group on Health Physics and Dosimetry of the President's Commission on the Accident at Three Mile Island. ORNL researchers found that, if they assumed a ground-level rather than an elevated release of xenon and krypton gases, they could obtain a calculated dose level that more closely approximates the dose measured by thermoluminescent dosimeters. This radiation dose, which is about 1% of that expected annually from natural background for the same TMI area population, is estimated to be too small to trigger any detectable health effects.

ORNL developed the modular health impacts assessment method for airborne releases of radioactive pollutants for the Office of Radiation Programs of the U.S. Environmental Protection Agency. Because the individual modules may be replaced without revising the entire system, the method offers a cost-effective approach to health impacts assessment, according to Rowena Chester, group leader. EPA has already used the ORNL method to assess more than 100 facilities having nuclear materials to determine whether they are operating in compliance with the Clean Air Act of 1977. EPA is not only employing the ORNL method for assessment of airborne releases but also has commissioned additional work using the ORNL method for determining radioactive pollutant transport in groundwaters and surface waters.

Four major projects have been under way at ORNL to develop this method for EPA. These projects have been cooperative efforts involving people in several divisions at ORNL (HASRD, Environmental Sciences Division, Energy Division, and Computer Sciences Division).

Fred Baes has led the effort in modeling atmospheric radionuclide releases, which has resulted in the AIRDOS-EPA and DARTAB computer codes used to set standards and to assess the TMI accident and the compliance of nuclear facilities with the Clean Air Act.

Keith Eckerman has been in charge of risk assessment, dosimetry, and health effects analysis for airborne radionuclides, including noble gases such as krypton, radon, and xenon. His group is developing a method, based on estimated effects of various levels of radiation on human organs, to estimate health risks to a population of 100,000.

Craig Little has supervised development of the environmental assessment model PRESTO for estimating the health effects of radioactive waste migration from shallow land burial sites. This method will provide data bases for shallow land burial sites (with widely varying soil and climatic conditions) at Barnwell, South Carolina; Beatty, Nevada, and West Valley, New York.

Additionally, David Fields has conducted a feasibility study to develop a computer code to estimate health impacts resulting from releases of radioactive pollutants to surface waters.

Computerized data bases developed for the ORNL method include a site data base that contains detailed demographic, climatological, agricultural, and land characterization information for 1/2 by 1/2 degree longitude-latitude cells in the continental United States. Says Chester: "This is the first such, and most extensive, data base to be prepared expressly for technology assessment needs." ornl

Visiting ORNL's New Hydrofracture Facility on the coldest day of the year are, from left, Tom Row, director of the nuclear waste programs at ORNL; John Seace, program manager for ORNL waste operations; and Herman Weeren, who was general overseer during the construction of the facility.

The New Hydrofracture Facility

Disposal of Intermediate Level Nuclear Waste

By BARBARA LYON

Whether radioactive wastes generated by nuclear reactors can be safely and permanently isolated is at the heart of arguments against the widespread use of nuclear energy. Many technical answers have been offered to this nagging question—proposals ranging from underground and ocean storage in metal drums to disposal of vitrified wastes in salt mines to rocketing fission by-products to the sun. For the most part, however, the technical fixes have been politically unacceptable.

Now, a method pioneered and used for years at Oak Ridge National Laboratory has withstood the test of time and has been endorsed by government agencies. Perhaps even more important, the method has not been panned by nuclear critics such as Fred C. Shapiro, author of *Radwaste*, the current book on past and present methods of nuclear waste disposal. In his recent article in *The New Yorker*, Shapiro conceded that the ORNL Hydrofracture Facility for sequestering intermediate level radioactive waste was successful. In fact, the ORNL burial site is the only successful permanent waste

Goetz Oertel, of DOE's Office of Nuclear Energy, spoke last fall at the dedication of the New Hydrofracture Facility.

disposal facility in the United States and probably in the world.

This was the observation made by Goetz Oertel, the Department of Energy's director of the Office of Waste Operations and Technology in the Office of Nuclear Energy, when he spoke at the dedication of the New Hydrofracture Facility for intermediate-level waste disposal last fall. The technology he referred to is one developed in the late 1950s and early 1960s at ORNL and is derived from a method for oil recovery used by oil companies in the West since just before World War II.

This inexpensive but elegant method of returning the isotopes to the rocks has withstood the test of 15 years, exhibiting no instability under exhaustive and sensitive monitoring. It is so successful that it is considered to be feasible for higher activity levels than those for which it is now being used, according to waste disposal experts in DOE and at ORNL.

The procedure is simple. A liquid—in this case a slurry about the consistency of buttermilk—is pumped into horizontal shale deposits some 300 m (1000 ft) below the surface with enough force to separate the layers of rock so that thin leaves of the material can be embedded. Spreading into a 2-cm-thick (1-in-thick) sheet with a radius of about 150 m (500 ft), the slurry, in the form of a cementitious grout, sets up into a monolithic solid which immobilizes the nuclear material indefinitely.

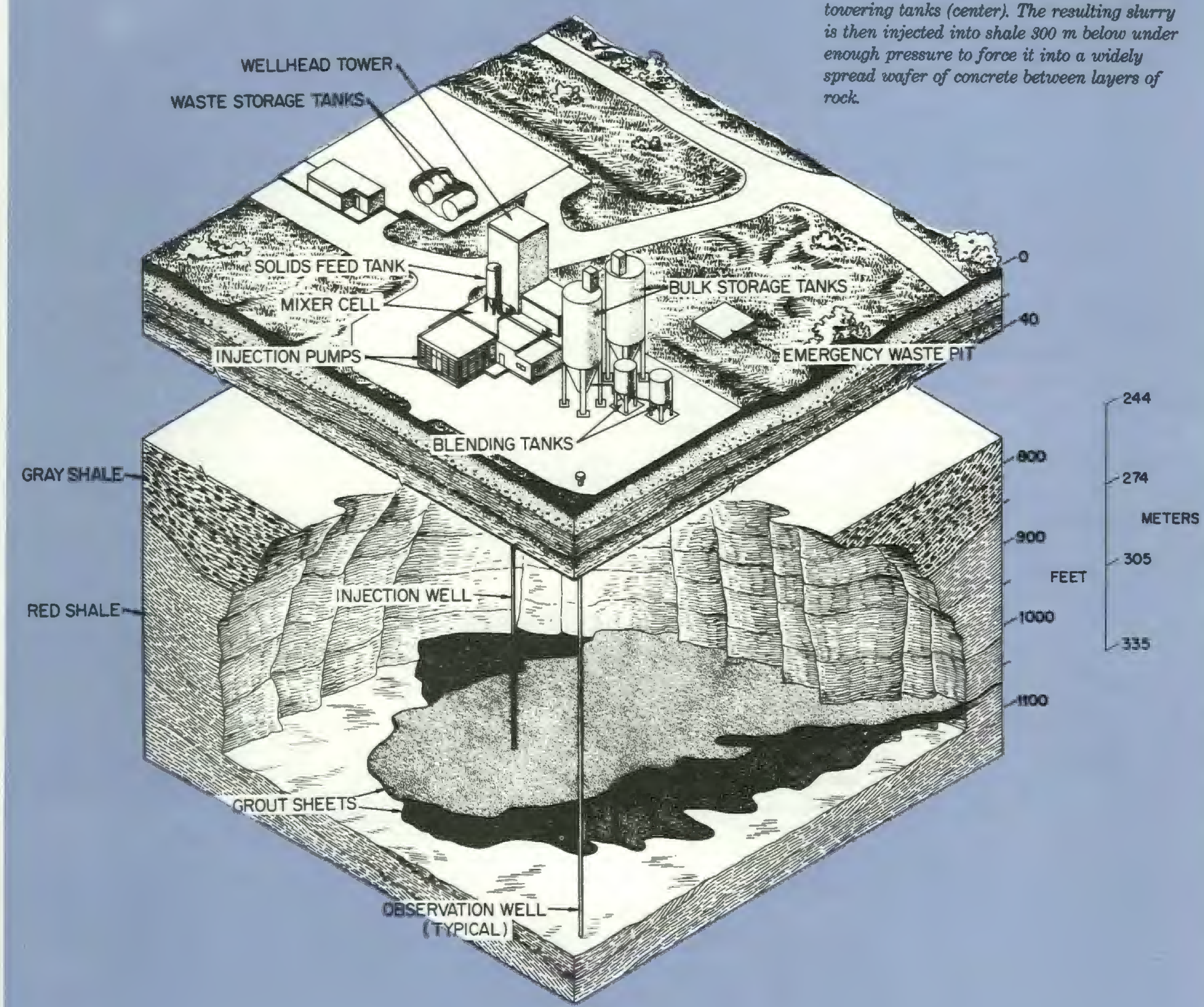
In exploring its possibilities in 1959, the late Wally DeLaguna, a geologist in the Health Physics Division, supervised three experimental injections to demonstrate the feasibility of the technology. Its success led to the decision to build the Laboratory's first hydrofracture facility, a pilot plant. Operation began in 1964 and the facility successfully buried approximately 5.7×10^4 m^3 (1.5×10^6 gal) of the Laboratory's low- and intermediate-level wastes in liquid form until it was shut down in 1979.

After fifteen years of pumping the radioactive cement underground, monitors over the burial area indicate that no movement or leaching of the material has occurred. Nor is it a particularly unusual rock formation that can support this kind of burial; any stratified layered rock will serve, although the grout must be mixed from compatible components. The mix used in Melton Valley is about equal parts local clay and fly ash, mixed with cement.

Project manager for the new facility is Herm Weeren of the Chemical Technology Division, currently on loan to the ORNL Radioactive Waste Management Program in the Operations Division. With Weeren's supervision, the present hydrofracture facility was designed and constructed to conform to today's standards for containment and reliability. It is capable of handling 300 m^3 (100,000 gal) per year, which it can dispose of in no more than two annual injections. Each batch operation takes about ten hours. Until enough waste is collected to warrant an injection, the primary waste is stored in underground holding tanks at the site, having been pumped there in 40-cm (16-in) pipes from the reactor buildings and hot labs that generated the material. The capacity of the pump used is about 0.95 m^3 (250 gal) per minute at 20.7×10^6 Pa (3000 psi).

Tom Row, director of the ORNL Nuclear Waste Programs, says the cost of operating the new facility comes to less than \$260/m^3 (\$1.00/gal) of disposed waste, and amortization of capital investment increases the cost to no more than \$394/m^3 (\$1.50/gal).

Many sites in the United States are suitable for this purpose. Both the Hanford and Savannah River sites look feasible, among others, according to Lotts, but so do about 75% of all the places considered. After all, this technique is practiced regularly in the petroleum industry. There, the drills commonly go as deep as 3050 m (10,000



This cutaway drawing of the New Hydrofracture Facility shows waste-bearing grout being pumped underground for permanent storage. From the underground tanks (upper left) the waste is transferred to the mixer cell, where it is combined with the clay and cement that have been stored in the towering tanks (center). The resulting slurry is then injected into shale 300 m below under enough pressure to force it into a widely spread wafer of concrete between layers of rock.

ft), whereas the ORNL facility stops at about one-tenth that distance. When asked why deeper wells have not been considered, Lotts replied that it was perhaps a matter of cost. Lotts also suggested that with deeper wells there is a risk of vertical fracture, although geological surveys performed in advance could avert such circumstances. He pointed out that the industry talks in terms of 6000 m (20,000 ft) for hydrofracture, and if that kind of depth is considered, vertical fractures can occur up to 300 m (1000 ft) long without causing serious problems.

The radiation level handled by the new facility will be higher than that of the experimental facility. Its capacity will be sufficient to accept wastewater of any level of radioactivity produced at ORNL, a level that Pete Lotts, former head of nuclear waste disposal programs at the Laboratory, estimates to be about 79 Ci/m^3 (0.3 Ci/gal). According to Lotts, the facility could probably handle ten times that level, though a limit far below this is clearly spelled out in the environmental impact statement. Indeed, some of the high-level waste does not preclude disposal by hydrofracture. For example, Savannah River waste activity levels are, on the average, about three times those at ORNL, and Hanford wastes are about the same as ours. Both sites are eyeing ORNL's technique of hydrofracture injection as a method of permanent disposal. ornl

TV on the Tank Farm

The three-year, $6-million cleanup of ORNL's "south tank farm" is nearing the end of its preparation phase—well ahead of schedule. A technique that should keep things going smoothly as the work enters its second phase is the use of specially adapted television cameras to keep a close—but safe—eye on the goings-on inside the waste tanks.

The tanks are located beside Central Avenue, diagonally to the cafeteria. For thirty-seven years they have held assorted radioactive wastes for the Laboratory. But the tanks, made of a sprayed concrete called gunite, were originally designed only as an interim solution, not for permanent storage. Now, with the intermediate-level waste system and the New Hydrofracture Facility complete, the wastes can be disposed of permanently and more safely.

The seven tanks contain about 1300 m^3 (roughly 350,000 gal) of radioactive sludge: a mixture of waste containing strontium, uranium, plutonium, cesium, cobalt, thorium, and europium. Because the material is radioactive and the people working on the cleanup operation need to keep an eye on what's happening inside the tanks—the drilling of holes for equipment, the insertion of the pump legs and sluicers, and the actual pumping-out—the method being used for this "eavesdropping" is a closed-circuit television system. There are two setups: a manually operated "temporary" rig, fitted with a camera borrowed from the Quality Assurance and Inspection Department, and a remotely controlled rig custom-built to withstand long operation in tough conditions.

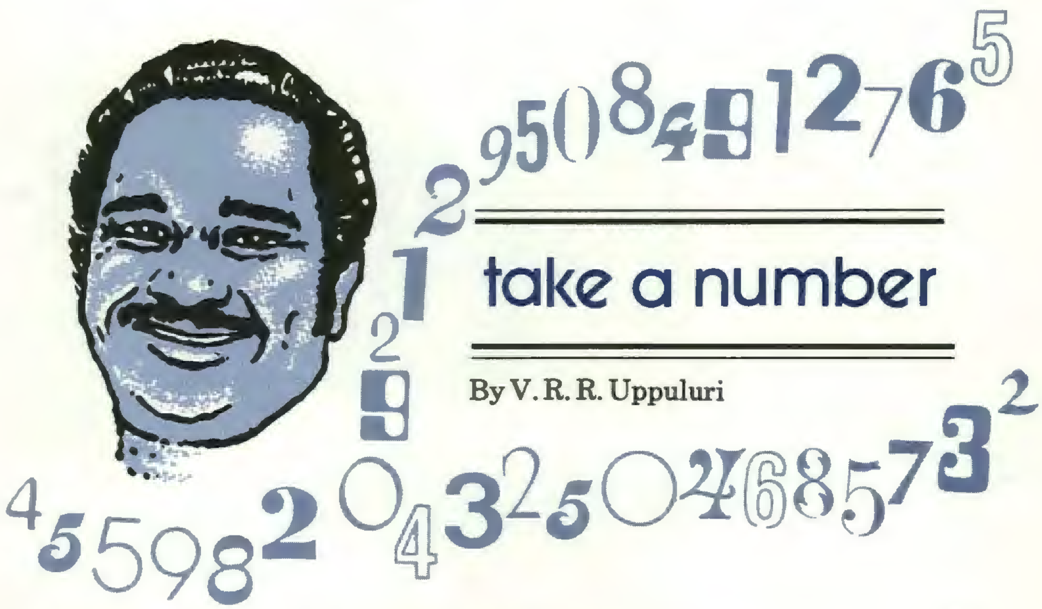
Both rigs are inserted through 60-cm-diam (2-ft) holes in the center of the tank domes. Their 7-m (23-ft) booms put them in the middle of the tanks; the booms can be maneuvered to let the cameras view any spot within the tank.

The temporary rig, which was available first, has already proved useful during drilling operations and inspections. It allowed examination of the walls and roofs of two tanks, determination of the amount and consistency of the sludge, and, most importantly, monitoring of the drilling of other access holes through the 75-cm-thick (2.5-ft) concrete. That monitoring helped confirm that the tanks are still in good condition.

The newer, permanent rig will give an even better look at the tanks: it has a more sensitive, low-light camera equipped with a 25X zoom lens. This rig will also be more versatile: it's equipped with water jets that can wash sludge from its lens and floodlights and protective clam-shell doors that will close during most of the pumping. According to Doug MacNary, project engineer for the preparation phase, the special rig may be used at other installations that have similar needs, such as Savannah River, once its job at ORNL is done.

During pumping operations, scheduled to begin next spring and continue for two years, both cameras will be used—the new one in the tanks as they're emptied one at a time, the other in an intermediate tank through which the sludge will circulate as it's being stirred up and then pumped out. A large platform, moveable from tank to tank, provides work space and supports the heavy television rig, drilling equipment, and pumping apparatus.

The tanks, which were built in 1943, gave no evidence of leaks during their years of use. When they are cleaned out, and their contents disposed of by hydrofracture at the new facility, they will probably be filled with sand or clay and kept in place.—J.W.J.



take a number

By V. R. R. Uppuluri

First Digits of Powers of Two

Let us look at the first digits of powers of 2: $2^0 = 1$, $2^1 = 2$, $2^2 = 4$, $2^3 = 8$, $2^4 = 16$, $2^5 = 32$, $2^6 = 64$, $2^7 = 128$, $2^8 = 256$, $2^9 = 512$, $2^{10} = 1024$, . . . ; they are 1, 2, 4, 8, 1, 3, 6, 1, 2, 5, 1, . . .

When we consider *all* the powers of 2, it can be shown that the digits 1 to 9 do not appear equally often, but with the following frequencies: 1, 30.1% of the time; 2, 17.6%; 3, 12.5%; 4, 9.7%; 5, 7.9%; 6, 6.7%; 7, 5.8%; 8, 5.1%; and 9, 4.6%. This is another example of Benford's law, which was discussed in a previous column.

Last summer, A. K. Rajagapal, professor of physics at Louisiana State University, observed that in the sequence of first digits of powers of 2, these five groups, or strings, appear: (1, 2, 4, 8), (1, 2, 4, 9), (1, 2, 5), (1, 3, 6), and, considerably farther on, (1, 3, 7). He raised the question of the relative frequency of these strings when we consider *all* the powers of 2. This was answered by David S. Scott, who gave the asymptotic frequencies of strings as follows: string (1, 2, 4, 8) appears 17.0% of the time; (1, 2, 4, 9) 15.2%; (1, 2, 5) 26.3%; (1, 3, 6) 22.2%; and (1, 3, 7) 19.3%. Recently, James B. Robertson, Professor of Mathematics, University of California at Santa Barbara, formulated this problem in the framework of ergodic theory and justified these results rigorously. His formulation enables one to determine the asymptotic frequencies of first digits of the powers of 3 and 4, etc.

Bob Blumberg came to the Laboratory in 1955, starting out in the Reactor Experimental Engineering Division, now Engineering Technology, where he remained until 1976. Within that period he spent a year on leave with the Weizman Institute in Israel. He acquired an expertise in remote handling and maintenance of nuclear reactors while working on Homogeneous Reactor and Molten Salt Reactor experiments. As a result, he was selected to design and supervise the development of the necessary equipment for the decommissioning of the Elk River Reactor in Minnesota in 1972–1973, after the Laboratory had been asked to help with the project. In the photograph he is standing at the now-empty site of the MSRE in Building 7503. On the opposite page, the Elk River Reactor is pictured. In his accompanying article, Blumberg presents the case for further development of a reactor decommissioning technology to cope with the large number of "spent" reactors that will soon be in our midst.

Decommissioning Reactors

By ROBERT BLUMBERG

About ten years ago, Pete Holz of the Reactor Division (now the Engineering Technology Division) hosted a delegation of visitors who wanted to see a demonstration of a technique called underwater plasma arc cutting that he and Clarence Wodtke had developed. This technique had been used for the remote repair of the Homogeneous Reactor in 1959. Clarence set up a demonstration in his laboratory and proceeded to cut slices of 2.5-cm (1-in) stainless steel plate under water, automatically and "gee-whiz-no-hands." The visitors were impressed, took copious notes on remote handling methods and went away with the slices of plate as souvenirs. That visit was the beginning of ORNL involvement with the dismantlement of nuclear reactors. The Laboratory was asked to provide the tools and techniques to segment the highly radioactive parts of the Elk River Reactor near Minneapolis, Minnesota. That was the world's first dismantling project. ORNL's contribution was vital and has been so recognized in the industry. It allowed the reactor to be dismantled with minimum personnel exposure to radiation. Since that time, however, ORNL has played only a small role in the flurry of activity in the field of decommissioning reactors.

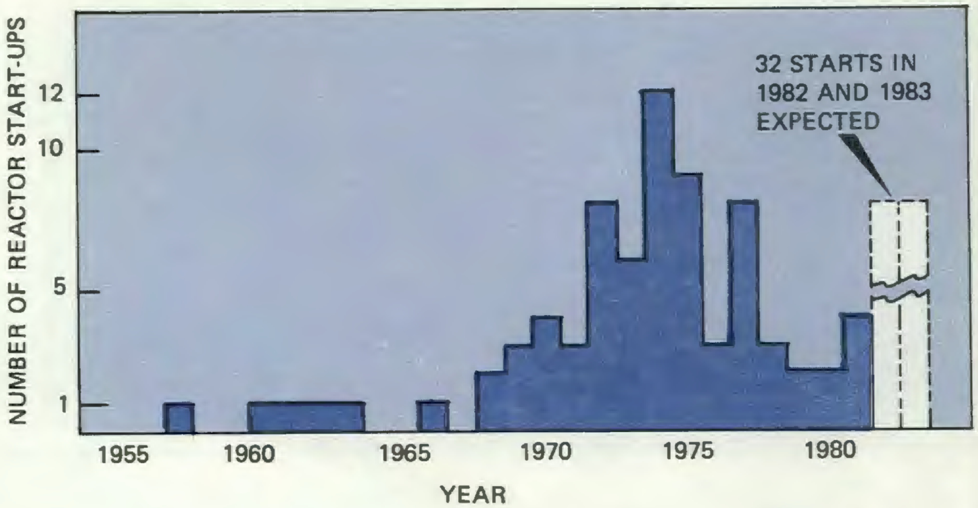
At the end of its operating life (30 to 40 years), a nuclear power plant enters a period of activity called decommissioning, during which the site is returned to a condition that is safe for human access and use. The problem is caused by residual radioactivity left over as a result of operations. The public's perception of the decommissioning process is that it is, at worst, not

feasible, and at best, dangerous and expensive. Here, I hope to review the problems, the experience, and ORNL's role in that experience and take a look at what can be expected in the future.

Three basic decommissioning methods are used to take care of the residual radioactivity coming from irradiated structural materials and the corrosion products that circulate within the reactor cooling system, generally referred to as "crud." These methods are entombment, safe storage plus delayed dismantlement, and prompt dismantlement. Because of its relatively long half-life (5.3 years), its high gamma-ray energy (1.3 MeV), and its presence as a tramp constituent in most metals, cobalt-60 is the predominant isotope—the enemy—that must be dealt with for the first 70 years of decay. At the end of that time, its radioactivity and the associated dose rate will have diminished by a factor of 10,000. After that time, the dose rate will be dominated by the decay of niobium-94, which has a half-life of 20,000 years. Thus, waiting longer than 70 years for the radioactivity to diminish does not have much effect.

Entombment

The method of entombment involves the emplacement of permanent barriers so that it is impossible for people and animals to gain access to the areas that are hot. The remaining structures can be removed, as in the case of the Hallam Reactor, or can be cleaned up and used, as in the case of the Piqua Reactor, which is now used as a municipal warehouse. Thus, the residual radioactivity is left in



The number of reactor start-ups reached a peak in the early 1970s. The number of reactors close to completion that are expected to be licensed in 1982–1983 is about 32.

place but is harmless by virtue of its inaccessibility. However, because of the long half-lives of two isotopes, niobium-94 and nickel-59, the radioactivity will not decay to unconditional release rates within the expected lifetime of any man-made structure. Therefore, permanent entombment is not seen to be an acceptable solution.

Safe Storage

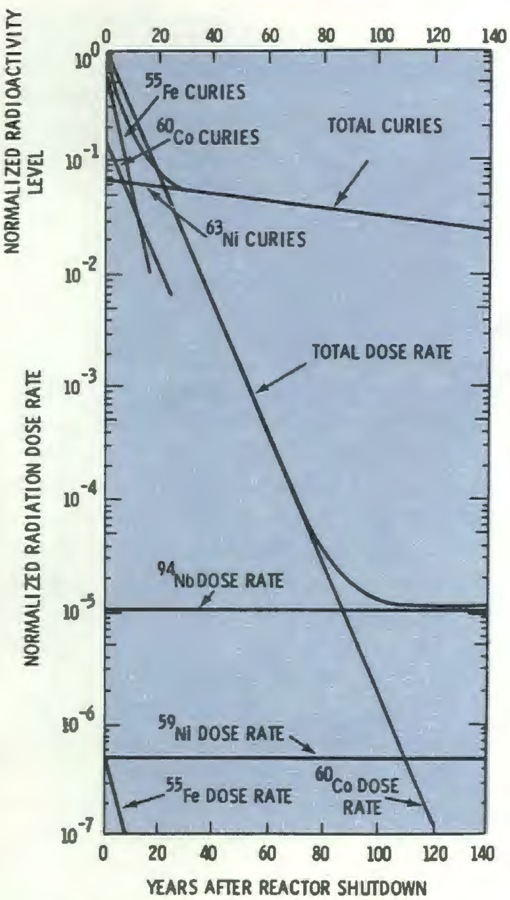
In safe storage, the radioactivity is sealed behind barriers of one sort or another to prevent intrusion, accessible areas are decontaminated, and some kind of site surveillance is used to ensure that no person comes in contact with the radioactivity. This method was used for Peach Bottom-1, EBR-1, and the Graphite Reactor (at ORNL). The latter two are national monuments. Whereas entombment is permanent, safe storage is considered a temporary condition. After 50 to 70 years, the radioactivity will have decayed to low enough levels to permit workers to use contact methods of demolition and materials handling to move the remaining radioactivity to a burial ground. In both the entombment and safe storage methods, standard construction techniques are used.

Dismantling

The third technique, dismantling, is one in which the radioactive parts of the reactor are shipped from the site to a licensed burial ground. Because no residual radioactivity remains, the site can be released for unlimited use. Dismantling is not a simple task because the parts of the reactor that have to be removed, namely, the reactor internals, the pressure vessel, and the nearby structures, were not designed with dismantling in mind. They are large and heavy, and have complex shapes. The size, weight, shape, and radioactivity make it difficult and expensive either to ship the components in one piece or to cut them up into smaller pieces that can be put into containers and shipped in shielded casks. Two reactors of significant size have been dismantled thus far: the Elk River Reactor and the Sodium Reactor Experiment, both with significant curie inventories, yet less by a factor of several hundred than would be encountered in a commercial nuclear power plant. A large—1100-Mw(e)—power plant operated for 30 years would have approximately 4.8 million curies at the time of shutdown, by comparison with the Elk River Reactor's 10,000 Ci. This radioactivity is associated mainly with the reactor internals and the pressure vessel. However, the liner and the concrete of the biological shield around the vessel will also be sufficiently radioactive to present problems of worker exposure in its handling. Although the segmenting technology developed at ORNL was successfully applied to the Sodium Reactor Experiment, it is unlikely that it can be applied to a large commercial plant without further development.

In contrast to the hot areas around the reactor vessel, the containment building and the auxiliary buildings should be relatively free from radioactivity and contamination. They can either be removed at some considerable cost or cleaned up and used.

The reactor plant owner, then, has two methods to choose from. The first, safe storage plus delayed dismantlement, leaves the radioactivity where it is, but provides barriers so that it is inaccessible to the public. After 50 years of decay, the remaining radioactivity is removed by standard construction techniques. The second method, prompt dismantling, removes the radioactivity within a short time (3 to 5 years after shutdown), but is a difficult process, involving high technology and worker exposure. The utility or government agency that has to choose one of these methods, at this point, has no clear-cut way of deciding which is best. The attempts that have been made to estimate comparable costs for the two methods have not shown a definite advantage for either. For a large, modern plant, costs of from \$60 to 100 million have been estimated for immediate disman-



Schedule of decay of reactor fission products following its shutdown. The total dose rate follows the decay rate of cobalt-60 for the first 70 years, after which the decay rates of other components predominate.

tling, whereas safe storage plus delayed dismantling is estimated to be a little higher. This cost translates to approximately 1.5% of the cost of electricity at the busbar. Uncertainties in the estimation process, such as the inflation rate and the tax laws, cloud the choice even further. Some site-specific factors which may be quite important have not yet been included in the considerations. One such factor is the value of the site or the value of the remaining structures put to some other use over the 50 years before delayed dismantling.

There are two technical areas in which further development could possibly reduce cost and worker exposure in reactor dismantling. These are in segmenting the large, highly radioactive components such as the pressure vessel and in the removal of the containment building. Because of stringent safety requirements, reactor containment buildings are probably among the strongest, most durable buildings in the world. The walls are heavily reinforced concrete about 1.2 m (4 ft) thick, and are very difficult to demolish. Ordinary demolition methods such as explosives and wrecking balls can be used, but they are not as effective or as efficient on this type of construction as they are on ordinary commercial structures. If the nuclear industry wants to or is forced to remove containment buildings, some innovative technology could lead to cost reductions.

Elk River Reactor

Segmenting the components of a typical light-water reactor involves the application of a technology such as that developed at ORNL for the Elk River Reactor. However, the Elk River technology is not adequate to satisfy the requirements for the larger—800- to 1100-h MW(e)—nuclear plants. These pressure vessels have carbon steel walls 20 cm (8 in.) thick, with a stainless steel cladding 4 mm (0.156 in.) thick, too thick for present plasma arc cutting torches to cut. Further development of cutting processes for the greater thickness of vessels and of remote handling methods for the higher radiation levels is necessary.

ORNL participated in the dismantling of the Elk River Reactor in an essential way. This was the first such project, and we extended the development of the underwater plasma arc cutting torch for this application. We combined the contributions of welding and cutting process development by Clarence Wodtke, mechanical design by Bob Beckers, instrumentation and controls by Bernie Lieberman and Bill Miller; my contribution was remote handling. The design of the plasma torch manipulator required special efforts by the ORNL fabrication shops in its construction. The remote handling skill was acquired at the various reactors that ORNL built and operated in the 1950s and 1960s. Ironically, with the reduction of reactor projects, people having that kind of experience have been moved to other fields, myself included.

After the Elk River Reactor, the Sodium Reactor Experiment in the Santa Susana Hills north of Los Angeles was dismantled by Rockwell International from 1976 to 1979. They used the plasma torch manipulator control console that had been used to dismantle the Elk River Reactor. Copies of all the ORNL manipulator drawings were sent to them, and three members of the Oak Ridge team provided advice and consultation during the planning program. The Rockwell International team made a significant contribution to dismantling technology by extending the capability of the remote plasma arc technique and by applying explosive cutting techniques.

Shippingport

Currently, DOE is planning for the prompt dismantlement of the Shippingport Reactor, in preference to delayed dismantlement. This reactor, which was the first commercial producer of electricity in 1957, is scheduled to be shut down at the end of 1982, at which time dismantling operations will begin. Clarence Wodtke and I have reviewed studies of dismantling methods for this project. The DOE-sponsored studies indicate a preference for removing the components in large pieces rather than segmenting them for convenience in handling and shipping. The use of the ORNL control console and the Rockwell International plasma torch manipulators at Shippingport is projected. The decision is yet to be made on the dismantling method—whether it will be by segmentation or one-piece removal—but there will be a need for the design, development, and testing of remote cutting tools, for which ORNL is a possible contractor.

A review of the status and growth of the nuclear power industry shows that the first of the large reactors, San Onofre with 436 MW(e) and Haddam Neck with 575 MW(e) came on line in 1968, making them ready for retirement around the year 2008, about 27 years from now. Before that, five or more smaller reactors will have to be decommissioned. After that, an average of five decommissionings each year will be necessary, corresponding to the reactors now in commercial operation. At today's costs, this may be a $500-million-per-year industry. It is impossible to foretell whether these decommissionings will require the high-technology equipment pioneered at ORNL for prompt dismantling or whether they will use the existing construction techniques of delayed dismantling. My own preference would be the latter: to find some useful function for their containment buildings, while allowing the radioactivity to decay for 50 years or so. Perhaps they could function as MX missile silos, parking garages, or away-from-reactor, spent-fuel storage facilities.

Early Retirements

A recent development may complicate the 40-year retirement schedule somewhat. Some eight to eleven reactors have been found to have a condition that may lead to premature retirement because of radiation embrittlement of the reactor vessel. The Metals and Ceramics and Engineering Technology divisions of ORNL are examining this problem in detail for the Nuclear Regulatory Commission. They are examining several approaches to extending the vessel lifetime. There is a slim chance that the methods of segmenting the reactor vessel could be used as part of an overall effort to replace the vessel in order to allow the balance of the plant a full or even an extended service life. For the same reason—radiation embrittlement of the reactor vessel—the Dutch government, in cooperation with the Joint Research Center of the European Community, is now planning to replace the aluminum vessel of their 40-MW High Flux Reactor at Petten, Holland, starting sometime in 1983. The HFR, a close copy of the Oak Ridge Research Reactor, is operated by the Dutch staff for the research needs of the European community. Its irradiation facilities are much in demand. As a result, a need exists to accomplish the changeover as quickly and efficiently as possible.

An underwater cutting method has to be used to dispose of the existing vessel, which is 5.5 m (18 ft) tall and 1.5 m (5 ft) in diameter and is made of 2.5-cm (l-in.) thick aluminum plate. Induced radiation from the trace amounts of cobalt-60 in the vessel will require the use of remote methods. Recently, I was invited to visit the facility as a consultant on equipment, procedures, and organization needed for such an operation. The work will require some remote tooling that must be designed, built, and tested in full-scale mock-ups. Although the equipment for this effort will not be as complex as the plasma torch manipulator, it will require help from outside the reactor operating and maintenance staff. An integrated system will have to be designed to satisfy the requirements of the remote, underwater operation. Some commercially available auxiliaries will be needed for lighting and viewing, as well as the long-handled tools that their staff is capable of supplying.

Nine years ago, when the Elk River job had been successfully completed, I thought that ORNL would have a continuing involvement in the field of decommissioning. The development effort to extend the segmenting technology from an Elk River sized plant to a large reactor did not materialize. However, DOE, NRC, and the utilities have made efforts in planning, writing procedures, and estimating costs, radiation levels, and personnel exposures associated with the decommissioning of the reactors in the United States. A modest technical literature on the subject exists, including several excellent references used in the preparation of this article. As I mentioned, one of the two available methods, delayed dismantling, can be implemented with existing technology (and patience). Finally, there is reason to believe that although the bulk of the decommissioning jobs may be two decades away, there will be ample opportunities in the interim to perfect any needed technology and that there will be companies waiting with the necessary skills and equipment to do the job efficiently and safely. ornl

lab anecdote

Cotton-Picking Fingers and Bristol Wrenches

A good practical joke should destroy no property—merely shake up the human spirit. When I was a graduate student, one chemist who felt left out of things because he had no electronic equipment in his lab found some vacuum tubes in a salvage bin, placed them on a chassis, and kept the filaments hot. When someone wandered by and asked what manner of equipment he had, Danny would answer brightly, "Oh, that's my seven-tube power waster." His machine worked at 100% efficiency for its purpose.

More elaborate was the Walker Educator Box. Clint Walker was an electrical engineer in the reactor controls group who couldn't keep his fingers away from a knob. When the controls group purchased an analog computer with its many knobs, Clint got more enjoyment from it than his coworkers cared to give him, and the Educator was the result. Griff Bates designed it, and he and a technician built it in short time: an electronic box adorned with knobs outside and containing a noisy horn inside.

The machine was left on a conference table. When Charlie Clifford came in and saw the machine, he inserted the power plug in the wall socket, attached the earphone jack, turned on the switch, and gave one of the knobs a twist. The horn began to wail. Nothing turned it off. The only function of the power cord and power switch was to turn on a red signal light. A 10-cm dial on the face had no function. The three ten-position knobs were really a kind of combination lock for which only one setting would turn the horn off and nine hundred ninety-nine positions would leave the horn sounding. The gain control didn't affect the horn.

"Well, why not open the lid and tear the wires out?" you may ask. That was possible if one had a screwdriver and first removed twelve screws. E. P. Epler later commented that instead of regular slotted screws, they should have used the rare bristol-head screws. "Why not carry the box out to the nearest creek and throw it in?" Fifty pounds of lead inside the box discouraged that idea.

The battery-operated horn with its latching relay kept sounding.

Sure enough, Clint with his light fingers went for the bait, but he was not the only one. When Epler told a calculator repairman what the purpose of the machine was, the man turned a knob. Epler was no more comfort to that hapless rascal than he was to a guard who phoned him at home one night to report that the horn was sounding. The guard didn't say that he had twiddled a knob out of curiosity, nor that he hadn't. Epler didn't tell him how to turn the horn off either.

The machine could also bite its design crew. When Steve Hanauer carried it down the hall one day, Wallie Koehler turned a knob as he passed by and let Hanauer worry about the noise. And when Clint Walker, who eventually learned the combination, left the box in the care of the group's secretary, Phyllis Groover, she reset the combination so that when Clint found someone to turn a knob and make the horn sound, even he was not able to use the combination to turn it off.

Walker left ORNL to work for TVA. The Educator Box left ORNL, too. Where to is not certain, possibly to K-25. There must be others who need some education.

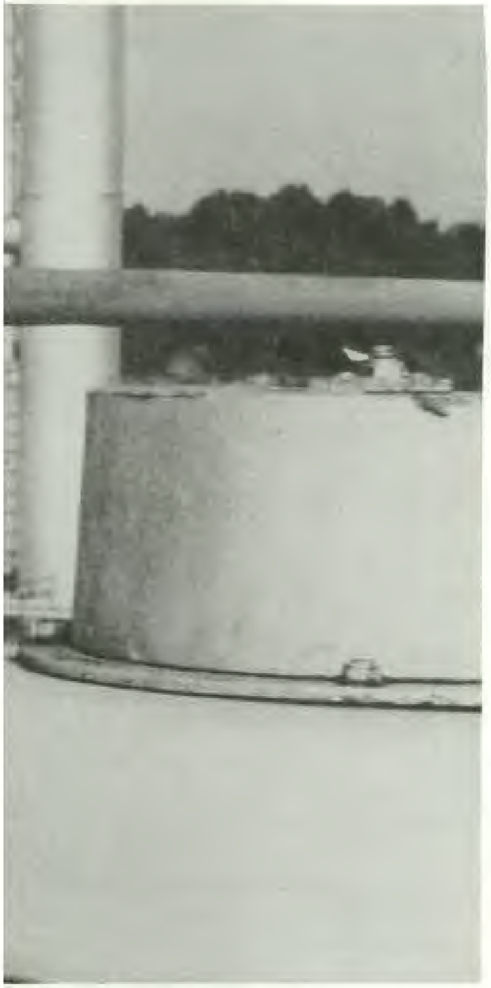
Pocket Monitors for Airborne Pollutants

By CAROLYN KRAUSE

Mr. Doe puffed on a cigarette and sipped his morning coffee while his 25-year-old son fed logs to a woodstove. "Well," Mr. Doe said, "I guess I'd better head for the lab," referring to the nuclear research facility nearby. "Do you have your badge?" asked his wife as she cooked her son's breakfast on the gas stove. "Yes," he replied. "I have my badge on, too," she said, fingering a gadget about the size of a small wrench clipped to her skirt pocket.

Mrs. Doe was taking part in an indoor air pollution experiment in which vapors in the home were being monitored, including cigarette smoke, woodstove emissions, and gases from cooking. Her "badge" contained filter paper which picked up room vapors. At the end of each day, the paper would be taken to a lab where scientists would use a spectrometer to identify and quantify the contaminants, some of which may pose hazards to human health. The son, who began work a week earlier at a local synthetic fuels plant, wore a similar badge on the job.

This is a scenario of what the future may hold, thanks to a recent achievement. A badge-size dosimeter that allows rapid and sensitive detection of airborne polynuclear aromatic compounds (PNA) has been developed at ORNL. Just as badges at nuclear installations can indicate radiation dosages to workers, the new vapor monitor has the potential of identifying and



Tuan Vo-Dinh tests his badge-size dosimeter at the H-Coal liquefaction facility in Catlettsburg, Kentucky.

measuring vapors of hazardous compounds in the workers' environment of synthetic fuels, pesticide, pharmaceutical, petroleum, and chemical industries. The device can also be used to monitor other airborne products of combustion such as motor vehicle emissions and indoor pollutants.

The PNA vapor dosimeter was developed by Tuan Vo-Dinh, a Vietnamese physical chemist who was educated at the Eidgenosische Technische Hochschule in Zurich, Switzerland. Since coming in 1977 to the monitoring and instrumentation group led by Dick Gammage in ORNL's Health and Safety Research Division, Vo-Dinh has impressed many people with his ingenuity. He has also devised a fiber-optics lightpipe luminoscope which detects contamination of skin by hazardous liquids produced during coal liquefaction. And he developed the technique of synchronous excitation phosphorimetry, which is already being used in England for oil spill identification.

Vo-Dinh's development of a PNA vapor monitor is actually a two-pronged achievement—the creation of a simple, cost-effective device and an advance in the state of the art of phosphorescence spectroscopy. For this achievement, Vo-Dinh received an IR-100 award in 1981 from *Industrial Research* magazine, which annually selects the 100 most innovative products of research that may have applications in industry. Recognition of the value of his work has come in other ways, too. Several companies have indicated an interest in manufacturing and marketing the PNA vapor monitor, and a publisher has asked Vo-Dinh to write a book on room-temperature phosphorescence.

The beauty of Vo-Dinh's development is that it offers a simple technique for complex chemical analysis. It is faster, less costly, and easier to use than the conventional methods of analyzing airborne contaminants, such as time-consuming extraction or desorption processes that use cumbersome pumps and other equipment. The vapor badge monitoring technique requires only chemically pretreated paper and a photospectrometer.

Vapor Paper

The heart of the PNA vapor monitor is a piece of filter paper coated with a heavy-atom chemical agent. By the process of molecular diffusion, PNA molecules in a worker's atmosphere are adsorbed onto the filter paper in the same way that the odor of burned tobacco is picked up by one's clothes in a smoke-filled room. After exposure the dosimeter is placed directly in a photospectrometer, which bombards the paper with a beam of light. The photons of light excite the electrons in the adsorbed PNA molecules. The excited electrons rearrange themselves, change their spin alignment, and then fall back to a lower energy state, giving off their excess energy in the form of photons having distinctive spectral properties. This light signal is called phosphorescence (which, unlike fluorescence, occurs not only during but also after the incoming radiation has been absorbed). The relative intensities of light emitted from the PNA molecules are measured by the photospectrometer, and these data are used to identify and determine the amount of the PNA species adsorbed onto the filter paper.

RTP Spectroscopy

Phosphorescence is normally a weak signal that is very difficult to detect. At room temperature, the signal is virtually quenched by collisions with molecules in solution or air. To reduce the probability of collisions, the conventional technique of phosphorescence spectroscopy has used costly cryogenic equipment to lower the temperature of the excited molecules so that the phosphorescence signal may be more easily detected.

In the past five years, Vo-Dinh has developed a simpler, less expensive technique—room-temperature phosphorescence (RTP) spectroscopy. He first began work on RTP during his postdoctoral research at the University of Florida, with an eye toward applying it to ionic compounds in medical drug analysis. When he joined ORNL four years ago, he began thinking about the chemistry required for monitoring PNA compounds, nonpolar species which are usually weakly phosphorescent. He experimented with a number of heavy-atom chemicals to determine which ones are most effective in enhancing phosphorescence in specific PNA species.

"Because heavy-atom chemicals have high atomic numbers, they possess considerable electronic charge that could perturb surrounding molecules," says Vo-Dinh. "It is known that the more electronic charge a molecule has, the more it will perturb the electronic state of other molecules such as PNAs. Known as the external heavy-atom effect in quantum chemistry, this perturbation increases the probability of spin-forbidden transitions leading to phosphorescence."

From his experiments with heavy-atom chemical agents, Vo-Dinh discovered that lead acetate effectively boosted the phosphorescence of benzo[*a*]pyrene (BaP), a carcinogen found in cigarette smoke and in the vapors emitted by coal conversion processes. Thallium acetate was found to aid the detection of pyrene, a coal conversion pollutant that is a co-carcinogen with BaP. Two other heavy-atom chemicals, cesium iodide and sodium bromide, were found to enhance the phosphorescence of other industrial vapors, such as fluoranthene and quinoline, the latter being a suspected skin and respiratory carcinogen.

In the laboratory, Vo-Dinh tested exposed dosimeter badges, estimated to cost $20 apiece to produce, by inserting them in a photometric analyzer, a type of photospectrometer that costs about $5000. After obtaining a phosphorescence signal from the inserted badge, Vo-Dinh compared this signal to a reference signal for identifying and quantifying the adsorbed PNA pollutants. He found that the analysis takes about five minutes and that the dosimeter's accuracy is 15% under laboratory conditions.

Analysis takes place after the desired exposure period has elapsed. Then the contaminated filter paper is analyzed, disposed of, and easily replaced with fresh paper. So far, Vo-Dinh's passive dosimeter has held filter paper treated with one or two chemicals, which permit the detection of several PNAs. To detect a greater variety of PNAs, it may be necessary to pack the dosimeter with several papers, each coated with a different heavy-atom chemical or a combination of several chemicals. More development work is needed to tailor the dosimeter to various industrial work environments and provide a simple but very specific monitoring device.

Field Testing

Initial field tests with the PNA monitor have already been conducted in the H-Coal liquefaction facility at Catlettsburg, Kentucky, and in coal gasification pilot plants at the University of Minnesota in Duluth and at Morgantown, West Virginia. With the help of his assistant, Gordon Miller, Vo-Dinh intends to perform further stringent tests in the near future.

If funding is available, Vo-Dinh and many of his colleagues in the Health and Safety Research Division would like to see the PNA monitor used to measure exposures to individuals in residential and occupational environments for correlation of hazardous chemical dosages with long-term health effects such as lung cancer.

"Regulatory decisions on air pollution control are often made without adequate knowledge of the health impacts of air pollution," says Vo-Dinh. "One of the weakest links in health effects studies is our knowledge of individual exposures. An urgent need exists to obtain dose estimates more representative of actual exposure. The passive PNA vapor dosimeter will be useful for monitoring personnel exposures and will provide information on which exposure levels are most likely to produce a specific health effect." ornl

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awards and appointments

Two members of the Laboratory staff were honored with the Department of Energy's E. O. Lawrence Award. **Fred Mynatt** and **Paul Selby** were selected to receive the award, which is given for outstanding work in nuclear science.

Calvin White was elected 1982 program chairman of the Materials Science Division of the American Society for Metals.

Harry Yakel was appointed associate editor of the *Journal of Applied Crystallography.*

Herbert Inhaber is manager of the newly established Office of Risk Analysis at ORNL.

Ray Johnson was appointed chairman of the Research Committee of the Nuclear Division of the American Ceramic Society for the 1981–1982 term.

Gene Goodwin was appointed chairman of the Welding Subcommittee of the EPRI Boiling Water Reactor Owners Group.

Jack Cunningham was appointed to a one-year term as vice-chairman of the Honors and Awards Committee of the American Nuclear Society.

Arthur Moorhead was appointed vice-chairman of the C3-D Subcommittee on Education of the American Welding Society.

Randy Nanstad was appointed chairman of the Fracture Toughness Subgroup for the *Nuclear Systems Materials Handbook.*

Phil Sklad and **Jim Bentley** received the Best in Show award for their display, Analytical Electron Microscopy of TiB_2-Ni Ceramics, in the metallographic competition at the 83rd annual meeting and exhibition of the American Ceramic Society in 1981. **David Stinton** and **Alice Richardson** were among the six winners of the contest to design a new logo for the society.

At the 1981 International Metallographic Exhibit, jointly sponsored by the International Metallographic Society and the American Society for Metals, first-place-winning posters were submitted by **Stan David, John Vitek, Paul Haltom, Rosemary Robertson, Phil Sklad,** and **Jim Bentley.** Second-place winners were **Vinod Sikka** and **Pete Houck**. Third place winners were **Bill Whiffen, Bruce Cox,** and **Tommy Henson.** Honorable mention was given **Ron Klueh, John Holbrook,** and **Houck**. The sponsors of the exhibit presented a plaque to **Bud DuBose** for his contributions toward making the exhibit an annual event. **Robert Crouse** has been named chairman of the 1982 exhibit.

James Blackmon shared the National Safety Council's Cameron Award for 1980 with **Harry Hoy**. Both are members of the R&D section executive committee of the NSC's Industrial Conference.

In a recent competition involving research programs at DOE laboratories, sponsored by the department's Division of Materials Sciences, **Bill Appleton, J. Narayan, C. W. White, Dick Wood,** and **Rosa Young** won the Outstanding Sustained Research in Solid State Physics award for their laser processing of materials.

Chet Richmond, John Storer, Michael Fry, John Auxier, and **James E. Turner** were elected to terms on the National Council on Radiation Protection and Measurements.

Robert McClung was named a fellow of the American Society for Metals. He has also been appointed chairman of the new Subcommittee on Nondestructive Testing Methods of the American Society for Testing and Materials.

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The Shippingport Reactor in Pennsylvania, the first commercial reactor to produce electricity, has been operative since 1957. It is to be shut down this year, and its dismantlement will involve ORNL technology. *See article on p. 28.* *(Photo courtesy of Duquesne Power & Light Company.)*