Radioactive Wastes: Some Urgent Unfinished Business

Many thoughtful people are now convinced that this country's nuclear enterprise will be in serious trouble unless the Energy Research and Development Administration (ERDA) demonstrates, and demonstrates fairly soon, that radioactive wastes can be permanently isolated from the human environment. Harvey Brooks of Harvard University, who is chairman of a National Academy of Sciences committee now evaluating the pros and cons of nuclear power, has put it this way: "No single aspect of nuclear power has excited so persistent a public concern as has radioactive waste management. . . . I would predict that, should nuclear energy ultimately prove to be socially unacceptable, it will be primarily because of the public perception of the waste disposal problem."

From its birth in 1946 until its demise in early 1975, the Atomic Energy Commission was responsible for managing nuclear wastes. But, by and large, the AEC never gave the waste problem the kind of priority that nearly everyone now thinks it deserved. Its stewardship was marked by a resort to temporary expedients that turned out to be not so temporary after all and by some hastily contrived attempts at longer-term or permanent disposal that proved abortive.

Two years ago, the burden of waste management passed to ERDA and the Nuclear Regulatory Commission (NCR) at the very time the nuclear enterprise was becoming a matter of growing controversy. Both agencies have been made acutely aware—in part by the lawsuits filed by environmental groups—that the public must be convinced that all dangerous and long-lived radioactive wastes, whether generated by the nuclear power industry or by ERDA's military plutonium-production processes, can and will be isolated from the biosphere for the several hundred thousand years that they will remain hazardous.

And ERDA, concerned lest further growth of the nuclear power industry be stymied at a time of rising oil imports, has felt particularly under the gun to show that the so-called "commercial wastes" from the power industry can be safely disposed of. Accordingly, for more than a year now the agency has had under way a $2-billion program to establish a system of deep geologic repositories for such wastes—although President Carter's energy adviser, James R. Schlesinger, now seeks to cut back the scale and pace of this program in order to give new prominence to a controversial interim storage facility known as the "Retrievable Surface Storage Facility." If and when the government squarely addresses the total waste management problem, of which the 30-year accumulation of "military wastes" is at present the larger part, it will be engaged in a massive effort that could require expenditures averaging $1 billion to $2 billion a year for the next two decades. The volumes of wastes that will be involved, and the logistical problems which they clearly imply, are large (see box, page 662).

Because of the huge volume of military wastes, the total cost of ultimate disposal could be something on the order of what it cost to put a man on the moon. To recover all of the high-level waste from the profusion of storage tanks—a difficult and uncertain task—and then solidify it for final disposal may cost as much as $20 billion, although all current estimates are little more than guesses. Then, the expense of establishing geologic repositories and handling and transporting all of the high-level and other military wastes could run the total bill up by another $2 billion to $3 billion.

Yet, however costly it might be to isolate the military wastes from the biosphere, many people believe it imperative that this be done. Leakage of waste from some of the storage tanks at both Hanford and Savannah River has been a persistent problem, although to date there have been no known human casualties. All told, nearly 500,000 gallons of waste have leaked from the tanks, with the most serious leak having occurred at Hanford in 1973 when 115,000 gallons of waste escaped from tank 106-T to the surrounding soil.

But, even if the military waste problem does not get the immediate attention that may be called for, the several plutonium-production reactors still operating and the nuclear Navy are not going to be shut down for that reason. This perhaps helps explain why neither the AEC nor ERDA has given the problem a high priority. On the other hand, as ERDA apparently perceives, it is entirely conceivable that a continued failure to deal properly with the commercial waste problem could result in the growth of nuclear power being slowed or arrested.

At any rate, ERDA began addressing this latter problem in a major way in 1975, and last year it got congressional approval to pursue plans to establish, by the mid-1990's, as many as six geologic repositories for the permanent disposal of commercial wastes.

The repositories would receive either spent fuel or—if the government and the nuclear industry decide in favor of fuel reprocessing and recycling—solidified high-level wastes and transuranic low- to intermediate-level wastes. Their total cost, estimated at $2 billion for construction, operation, and all related R & D, is supposed to be recaptured from the utility industry through disposal fees.

The first two repositories, scheduled to be ready to receive wastes in 1985, would be built in large salt formations, at a depth of from one thousand to several thousand feet below the earth's surface (see figure, page 664). Later repositories might be built in shale or crystalline formations such as granite or volcanic basalt. A particular advantage seen in salt is that it flows plastically, and, once disposal of the wastes has been made final by backfilling a repository's chambers and passageways with crushed salt, the repository is expected to be self-sealing as the formation settles and again becomes a solid mass.

The concept of deep geologic disposal was first put forward 20 years ago and ERDA believes that carrying it out will require no more than "straightforward technology and engineering development." There are other concepts, such as deep seabed disposal, ejection of wastes into outer space, and transmutation of troublesome radionuclides into more benign forms, but none of these is regarded by ERDA as feasible for the near term.

The marked proclivity to short-term expedients which the past history of waste management reveals is more understandable for the early nuclear years than for the more recent years. During World War II and the immediate postwar period there was probably no real possibility, given competing priorities, of developing a means of permanent disposal that would remove the military wastes from the biosphere.

But later, when a start might have

The Radioactive Waste Inventory

The weight of the waste management and regulatory burden that ERDA and NRC have assumed is apparent from a look at the commercial and military waste inventories, existing and prospective.

The commercial wastes. The inventory of spent fuel on hand today in temporary storage (nearly all of it in water basins at power plant sites) is comparatively modest, as only about 2500 metric tons of such fuel has thus far been discharged from the 64 reactors now operating. But, by 1985, when there will be at least 136 reactors on line, the inventory will have grown to nearly 25,000 tons. And, if the growth of the nuclear power industry matches the NRC's projections, there will be more than 125,000 tons by the year 2000, or the accumulation expected from the operation of about 500 large reactors.

If disposed of as waste and not reprocessed for recovery of plutonium and unconsumed uranium, these tonnages can be translated into thousands upon thousands of large waste canisters (some 10 to 15 feet in height and 12 inches in diameter) emitting both heat and dangerous high-energy, penetrating radiation. Indeed, by the year 2000 there could be as many as 400,000 such canisters.

If the spent fuel is reprocessed, the resulting volume of wastes will be even greater than if it is not. There will be only about a tenth as many canisters of reprocessing (or "high level") wastes giving off heat and high-energy radiation, but there will be a great outpouring of chopped-up fuel cladding and other trash that has been contaminated with transuranic elements, especially plutonium.

In fact, by the year 2000, the equivalent of more than 700,000 55-gallon drums of such "transuranic wastes" could accumulate, and, like the high-level waste, all of it would need to be disposed of so as to ensure isolation from the biosphere for hundreds of thousands of years. In addition, there could be a need to dispose of as many as 20 million drums of "low-level," nontransuranic wastes, which would be generated whether there is reprocessing or not. (Less demanding than the high-level and transuranic wastes in the isolation required, such low-level waste may be properly disposed of through burial in deep trenches.)

The military wastes. All of the high-level military waste, some 75 million gallons of it, is currently stored in about 200 underground tanks of up to 1.3 million gallons capacity each at ERDA's Hanford, Savannah River, and Idaho Falls installations. Because the fuel in plutonium-production reactors is irradiated less than the fuel in commercial power reactors, the wastes produced contain fewer fission products than do commercial wastes and therefore are not as "hot," either radiologically or thermally. Nevertheless, like the commercial waste, this military waste must be kept isolated from the biosphere for what, in the human perspective, is essentially forever.

If an effective program aimed at permanent disposal is soon initiated, the total volume of solidified waste on hand by the year 2000 could come to 11 million cubic feet, or enough to fill more than 90,000 huge canisters, each one 10 feet in height, 4 feet in diameter, and weighing as much as 8 to 10 tons. In addition, at least 1 million drums of low- to intermediate-level transuranic waste—much of which already has been packaged and buried in a retrievable mode—will have to be committed to repositories. Also, if the expensive, time-consuming, and possibly hazardous attempt is made to recover all of the transuranic waste that has been buried without provision for retrieval, room will have to be found for still another million drums.

Should the military and commercial waste inventories grow as ERDA and the NRC foresee, by sometime after the turn of the century it would take a thorough mixing of the hazardous radionuclides in the waters of all the world's oceans to lower the concentration to within presently acceptable limits. And, perhaps by the middle of the 21st century, the radioactivity could be quite beyond all possibility of dilution to safe levels. The hypothesis is of course farfetched, for no such mixing could conceivably occur. But, by the same token, the potential for contamination of local and regional environments is significant.—L.J.C.

been made toward establishing repositories for final disposal, there seems to have been little inclination on the part of the AEC to do this. Last July at an ERDA-sponsored international symposium on waste management, Harvey Brooks, who was serving as a nuclear physicist and engineer early in the nuclear era, observed: "In the first years after the war the waste disposal problem was never attacked with a real sense of urgency. Research and development expenditures were relatively small, and the whole problem had little prestige or glamor among the scientists and engineers who were being attracted to the new and growing field of nuclear energy."

But even when forward-looking proposals for waste management were advanced, the AEC, perhaps reflecting a cold war preoccupation with nuclear weapons development and also busy with naval reactors and an infant commercial power program, did not follow up effectively. In 1957, when the National Academy of Sciences committee on radioactive waste disposal (a body which had been formed at the AEC's request) proposed that high-level wastes be solidified and put in deep geologic disposal, the AEC response seems to have been typical. Instead of doing as the committee had suggested and searching for the most stable and secure geologic formations available (salt was especially recommended), the agency, with an eye to cost and convenience, wanted to establish repositories on-site at its Hanford, Savannah River, and Idaho Falls installations where the wastes were being generated.

In fact, except for undertaking some experimental work at a salt mine near Lyons, Kansas, the AEC gave short shrift to all of the committee's advice.* And, when another critical report was submitted in 1966, the agency suppressed it and cut off the committee's funding.

Some of the AEC's other management decisions in the 1960's also seem to have rendered the waste problem less tractable than it might have been otherwise. From the beginning of the plutonium production program at Hanford and Savannah River, the high-level waste from the reprocessing plants—waste which is acidic and potentially corrosive—has been neutralized by the addition of sodium hydroxide to make it suitable for storage in carbon steel tanks. But this doubles the waste's total volume and

*The unhappy relationship that existed between the Academy committee on waste disposal and the AEC is described in detail by Philip M. Boffey in *The Brain Bank of America* (McGraw-Hill, New York, 1975).

makes removal of all of the waste from the tanks quite difficult.

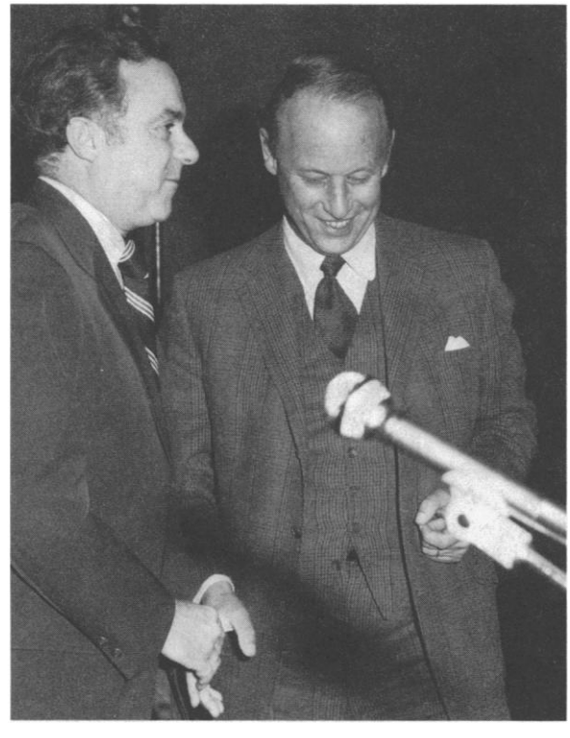
By the 1960's, what with the waste inventory still growing and the storage tanks proliferating and sometimes leaking, it was evident that something had to be done. And, as a matter of fact, an attractive waste management alternative was demonstrated in 1963 at the AEC's national laboratory at Idaho Falls, where high-level wastes from the reprocessing of spent fuel from experimental and naval reactors had always been left in their acidic state and stored in corrosion-resistant stainless steel tanks. What the laboratory now did was to start running these wastes through a simple, relatively inexpensive high-temperature process to convert them to "calcine," a granular material somewhat like a fine sand. This calcining process, which has been used continuously ever since, reduces the total waste volume by a factor of 9 or 10 and changes the waste into material which the laboratory confidently believes can be incorporated into glass for permanent disposal. (Unless immobilized as a solid the wastes might eventually migrate.)

Although perhaps stuck with the large volume of neutralized wastes already in storage at Hanford and Savannah River, the AEC could have gone to stainless steel tanks and the calcining process for

Califano Praises NIH, Retains Fredrickson as Director

In one of his first appearances as new Secretary of Health, Education, and Welfare (HEW), Joseph A. Califano, Jr., dropped by the National Institutes of Health (NIH) last week to sing the praises of biomedical research and start making good on a promise to "depoliticize" the institutes. Speaking before an overflow crowd of NIH scientists and other employees, Califano called NIH one of our "greatest national treasures" and then expansively added for good measure that he thinks it "one of the great treasures of the world." With that, he announced that he has asked Donald S. Fredrickson to stay on as NIH director, a position he has held since April 1975, when he was appointed by former President Gerald Ford.

Califano clearly brought a welcome message to NIH researchers, who rose to their feet and cheered Califano's announcement that Fredrickson would stay. Fredrickson, a Republican, is a popular director and the biomedical community nationally was plugging to have him remain on the job. His retention seemed likely when Califano declared, in response to a reporter's question during his first press conference on 26 January, that he would remove partisan politics from NIH. Nevertheless, the apprehensive were relieved when the decision to keep Fredrickson became official. The fact that Califano took the trouble to go out to NIH's campus in Bethesda, Maryland, to deliver the word in person was even more reassuring.



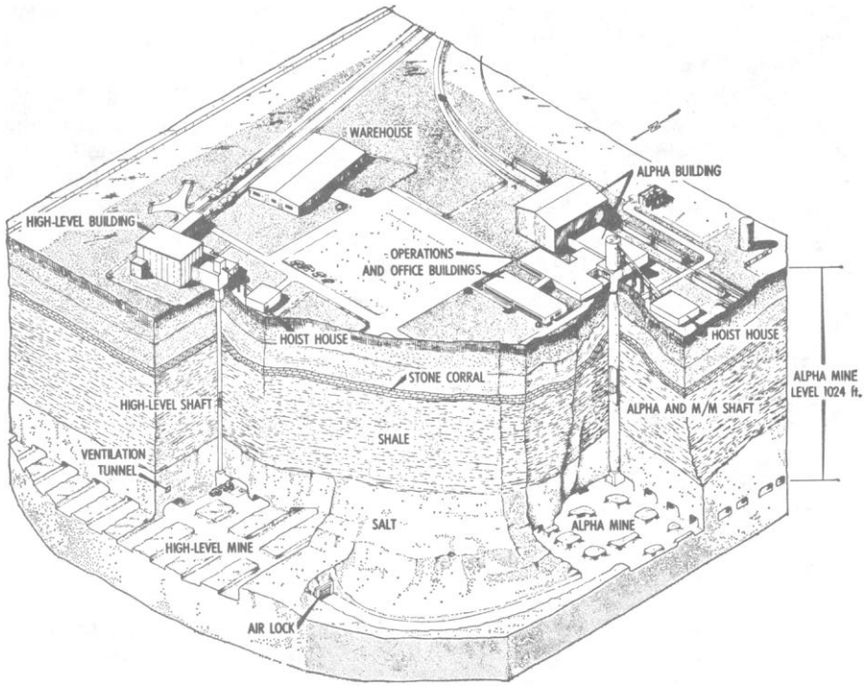
Joseph A. Califano, Jr. (left) and Donald S. Fredrickson

The Secretary told his audience that he had asked Fredrickson nothing about his political views and promised that, during the next 4 years, persons being considered for NIH advisory committees would not be asked about their political views either. "I hope you understand the meaning in the larger sense of asking Dr. Fredrickson to stay on," Califano said. He realistically noted that he cannot protect NIH from all political pressures to conduct certain kinds of research or to emphasize ethical and social concerns, but he said firmly, "as far as partisan politics is concerned, it is out of NIH." Not only that, he added that his message comes also from President Jimmy Carter, who "understands your need for an apolitical environment in which to work." The crowd loved it, especially when he called basic research "critical to our society," and said, "It needs added resources and I'll try to get them for you."

In exchange for his support, Califano asked two things from NIH. First, a promise of "excellence" in research. Second, a commitment to advancing opportunities in science—by opening the doors to graduate schools—to women, minorities, and handicapped individuals. "I will not stand for the myth that excellence is inconsistent with opening the doors of our great research universities," he said and informed NIH'ers that he expects them to take the lead in providing equal opportunity.

Califano told the researchers things they have been waiting to hear for eight Republican years—that they are important, appreciated, special—and he did not leave anything out. In fact, his remarks sounded almost as if they could have been written by NIH's patron saint and former director James A. Shannon. To be sure, Califano's visit to NIH was just a political gesture, and NIH will have to fight as hard for its needs with the Administration and Congress as any other special group. But in politics, gestures can be important and Califano was telling the biomedical research community early in the game that he considers them worth the gesture.

When it was all over, about 20 minutes after it began, Fredrickson, who wanted more than anything to stay at NIH, thanked the Secretary for "an enormous message and one of great hope." Now, it's back to real life.—B.J.C.



Commercial waste repository.

all newly generated wastes. The fact that it chose not to do so is significant, for about a third of all the high-level waste in inventory at those installations today has been generated since the mid-1960's.

In 1965, the agency did begin separating the principal heat-generating radionuclides from both new and old neutralized wastes and using evaporators to convert the bulk liquids to a damp salt cake, thereby reducing the volume by a factor of 5 and making bad leaks less likely—but making removal of the wastes from the tanks more difficult still. (Almost half the waste is now in salt cake.) As an interim measure for coping with the existing waste, this seems to have been wise. But, while it is also true that this was the cheapest way in the short term to cope with the new waste, it offered not nearly the advantages of calcining in terms of volume reduction or progress toward ultimate disposal. Solidification of the salt cake or its dangerous radionuclides in glass can apparently be accomplished, but at a price far higher than what it costs to calcine and solidify acidic wastes.

By the end of the 1960's, circumstances compelled the AEC to give the matter of establishing geologic repositories a higher priority. When, in the aftermath of the disastrous 1969 fire at the AEC weapons facility at Rocky Flats, Colorado, the agency began shipping large amounts of debris that had been contaminated with plutonium to the waste burial ground at Idaho Falls, state officials objected. They said that Idaho should not be the place for permanent disposal for such material, and also insisted on eventual removal of the plutonium-contaminated wastes that had been routinely buried there in the past. The upshot was that the AEC agreed to start removing such wastes as soon as a repository became available.

Another compelling circumstance was the fact that commercial wastes would soon be generated in substantial volume. Indeed, several fuel reprocessing facilities were due to begin regular commercial operation by the mid-1970's and it was clearly unthinkable to repeat what had been done in the case of the military wastes by allowing another proliferation of underground tanks for the indefinite storage of high-level wastes. In 1970 the agency declared, as a matter of policy, that all commercially generated high-level wastes would have to be solidified within 5 years by the fuel reprocessor and transferred to a federal repository no later than 10 years after reprocessing.

Finally persuaded that the need to provide means for permanent geologic disposal of wastes was indeed pressing, the AEC also decided, at least tentatively, to make the salt mine at Lyons, Kansas, where it had been doing experimental work, a prototype national repository. But even as this decision was announced, William W. Hambleton, director of the Kansas Geological Survey, was raising questions as to the geologic integrity of the Lyons site.

Representative Joe Skubitz of Kansas challenged the AEC decision and, in 1971, Congress directed the agency not to proceed until the repository project could be certified as safe. After it was learned that numerous exploratory oil and gas wells had been drilled near the site and that some 175,000 gallons of water had mysteriously disappeared during the hydraulic fracturing operation once attempted at a nearby salt mine, the AEC abandoned the Lyons project in early 1972.

Shortly thereafter, the agency initiated a project to establish a geologic repository near Carlsbad, New Mexico, for intermediate-level transuranic wastes from the weapons program. Several years later, in 1975, this project (which is still in progress today) suffered at least a temporary reversal when a big pocket of brine was discovered deep inside the salt formation at the specific site then being investigated. This setback could have been avoided had AEC officials in Washington done as the project contractor suggested and let further geophysical exploration precede the drilling.

A few months after the embarrassment at Lyons, the AEC, still eager to come up with a solution to the commercial waste problem, announced a stopgap. Pending availability of a geologic repository, the agency proposed that the Retrievable Surface Storage Facility (RSSF) be established to provide safe storage for commercial and military high-level wastes for up to 100 years. The RSSF was to consist of a large field of numerous individual concrete mausolea into which thick-walled casks containing canisters of solidified wastes were to have been inserted; the wastes were to be cooled by natural air flows. It would have been built at an AEC installation in the West, probably either Hanford or the Nevada Test Site.

But, upon reviewing the proposal, the Environmental Protection Agency expressed uneasiness. It was afraid that, because the RSSF would be relatively cheap, it might be palmed off as a permanent low-budget substitute for deep geologic repositories. Stung by this criticism and conscious that commercial reprocessing was not going to be coming along as soon as had been expected, the AEC's successor agency, ERDA, in April 1975 gave up its plan for early construction of the RSSF and began developing the plan for a system of deep geologic repositories.

As the plan has been conceived, work toward its implementation could continue even should there be more reverses such as the one at Lyons. By providing for the selection of multiple sites, with two or more in salt and others in shale

and granite, at least some of them would be expected to prove usable. Two of the six repositories proposed could accommodate all of the commercial wastes to be generated by the year 2000. And, for some years after a particular repository has been opened, the wastes committed to it could be retrieved if trouble should develop.

The same redundancy of approach is to be followed with respect to the development of technologies for the solidification of high-level liquid wastes. Initial demonstration of these and other relevant technologies—such as those for reducing the volume of transuranic wastes—is scheduled to be completed in 1978. This may be ambitious, however. An NRC study of management alternatives for the now-defunct Nuclear Fuel Services reprocessing operation at West Valley, New York, found that to develop an operational process for vitrifying (converting to glass) the 600,000 gallons of neutralized high-level wastes now in tank storage there would take 14 years.

Besides hedging against unexpected geologic or technical problems, the ERDA plan for multiple repository sites has been designed to assure the various states that no one of them will be asked to take all of the nation's high-level and transuranic wastes in its own backyard. Nevertheless, trouble arose late last spring in northern Michigan when word spread that ERDA was about to begin exploratory drilling in Alpena County.

The trade magazine *Nucleonics Week* had reported: "Union Carbide [the ERDA contractor in charge of the commercial waste program] is moving into the final stages of its waste isolation site-selection program with the salina basin [salt deposit] in Michigan and the [gulf state] salt domes leading the list." A Union Carbide official was quoted as saying that Alpena and two neighboring counties had been singled out for intensive investigation. Subsequently, the Michigan press was full of stories quoting various local officials and citizens who wanted ERDA to stay out of Michigan. And, as the result of questions raised by Representative Philip E. Ruppe, the Republican congressman for Alpena County and most of the remainder of northern Michigan, ERDA gave up its plans for exploratory field work in that region, at least temporarily.

Meanwhile, the pressure on ERDA to make good on its repository plan, with no more failures or delays, was mounting sharply. Although California voters last June rejected the nuclear ballot initiative that would ultimately have shut down all nuclear power plants in the absence of a

Ousted Seamans No Fan of Schlesinger

Robert C. Seamans, Jr., the soft-spoken, gentlemanly head of the Energy Research and Development Administration (ERDA) since it was created in 1974, is leaving his job, miffed at the way he was dumped by the Carter Administration and harboring less-than-enthusiastic thoughts about Carter's energy czar, James R. Schlesinger.

Seamans, 58, whose long career in Washington includes stints as deputy director of the National Aeronautics and Space Administration, Secretary of the Air Force, and president of the National Academy of Engineering, let it be known some time ago that he was willing to stay on as head of ERDA until the Carter Administration gets its energy plans sorted out. He reasoned that, with a massive reorganization of energy agencies in the works, it would make sense for him to stay and provide some continuity during the changeover period.

Robert C. Seamans, Jr.

Those thoughts were communicated to a few colleagues, congressmen, and journalists. But when Seamans tried to get an appointment with Schlesinger a few weeks before Inauguration Day to explore the new Administration's thinking, he was unable to do so. That, as any student of bureaucratic power games knows, should have been the tip-off. Then, during inauguration week, Seamans says he "heard indirectly" (through whom, he won't say) that he didn't fit into the Administration's long-term plans but could stay on a few more weeks if he wanted.

Feeling a bit miffed at the way his dismissal was being handled, Seamans sent Schlesinger a note on 18 January announcing that he was resigning effective 20 January—Inauguration Day—but would be willing to help out in some capacity if Schlesinger desired. Finally, on 19 January, the two men held a telephone conversation and Schlesinger asked Seamans to serve as a "consultant" for a while, a designation that let Seamans clear off his desk, kept his security clearances alive, and enabled him to put the finishing touches on a new planning document.

The indirect nature of his dismissal left the usually mild Seamans angry, according to some of his acquaintances. Seamans is circumspect about discussing his departure with reporters but it seems clear that he has no great admiration for Schlesinger and that this feeling existed even before he was dumped out of his job at ERDA. This is apparent less in what he says about Schlesinger—indeed, he never says anything explicitly derogatory—than in a general lack of enthusiasm about Schlesinger. At a breakfast meeting with reporters on 22 December, Seamans described Schlesinger as a man of analytic bent who thinks in global terms but who is often "Delphic," puffing his pipe and leaving his listeners unsure just where he stands on an issue. Beyond that lukewarm evaluation, Seamans would not go, despite repeated pressing by the reporters.

In a recent valedictory interview with *Science*, Seamans again said Schlesinger has "great mental capacities," as well as "a lot of experience." But when asked if he thought Schlesinger was a good choice to fill the Carter Administration's top energy post, Seamans simply said, "I hope he'll succeed. He's got to prove himself." Seamans said that the energy area is very different from the agencies that Schlesinger formerly headed—the Defense Department, the Central Intelligence Agency, and the Atomic Energy Commission—because those agencies were ongoing enterprises "where the whole thing doesn't evaporate if the top guy doesn't do very much." But in the energy area, Seamans said, new Administrative structures must be carved out, people have to be motivated, and great political savvy is required to get Congress, the Executive Branch, and numerous disputing groups to cooperate in solving the energy crisis. "History will show what his [Schlesinger's] capabilities are in this area," says Seamans, as he prepares to return to private life, undecided about what he will do or where he will live.—P.M.B.

permanent and safe system of waste disposal, the state legislature enacted a law that could stop further growth of nuclear power under such circumstances.

Also, as the result of a U.S. Circuit Court of Appeals ruling in July, the NRC stopped issuing reactor construction permits or full-power operating licenses, pending further analysis of the environmental and health hazards associated with fuel reprocessing and waste management. Although licensing has since been resumed under a stay of the court order, the Natural Resources Defense Council (NRDC), an environmental law group, continues to press for a moratorium or slowdown on expansion of nuclear power until the NRC formally determines that radioactive wastes will in fact be disposed of safely.

Terry Lash, the NRDC staff scientist involved in the litigation, regards geologic disposal as promising but is afraid that ERDA, in its haste to eliminate the waste management issue as an impediment to the growth of nuclear energy, will make mistakes that will lead to another grand foul-up. "It's important to be very deliberative," he says, "yet they [ERDA officials] are running around like chickens with their heads chopped off—and this after 20 years when nothing was done."

Obviously anxious to avoid further troubles of the kind encountered in Michigan, ERDA sent letters late last fall to 36 governors, informing them of its plans for conducting field investigations or geologic literature searches in their states. It was emphasized that the first two sites would not be chosen before the nationwide search is completed in 1978 and that no site would be selected over a state's objections. "Anyone who thinks this is a matter for federal preemption is out of his goddamn mind," one ERDA official remarked to an interviewer from *Science*. Agency officials say that thus far, no state has refused to cooperate, though the attitude typically is one of caution and reserve. In Michigan, Governor William G. Milliken's ad hoc advisory task force on nuclear waste disposal recommended in December that ERDA's geologic investigation should be allowed to proceed there if certain conditions and safeguards are met. Also, New Mexico's Legislative Energy Committee has proposed—though not without stirring up some local controversy—that a demonstration nuclear fuel cycle center, which would include a waste repository, be established in that state.

In view of the emphasis that Jimmy Carter put on nuclear safety during his campaign last year it seems surprising that there should now be serious talk of again looking to the RSSF, or surface repository, concept for a possible interim solution. But this is precisely what has been going on during the transition to a Carter presidency. As chairman of the AEC in the early 1970's, James Schlesinger favored the RSSF concept. And, after being named Carter's energy adviser, he called on ERDA to develop an alternative plan directed at having an RSSF as well as one or two deep geologic respositories by the mid-1980's.

The idea would be to rely perhaps on the RSSF as the backup if technical or political difficulties made it impossible to use the first geologic repository developed. Also, the scope of the search for geologic repository sites could be narrowed because, as Schlesinger reportedly assesses the situation, there would not be a need for more than three or four such repositories for the foreseeable future.

Seamans Takes Exception

Robert C. Seamans, Jr., who has just left his job as administrator of ERDA with the change of administrations, thinks Schlesinger could be making a bad mistake. Although Seamans does not object to building an RSSF for extra insurance, he thinks that there should be no change in the scale and pace of the existing plan to develop geologic repositories, with the first two being established in pairs and with each available as a backup to the other. "You are just temporizing with the RSSF," he told *Science*.

William P. Bishop, chief of NRC's waste management program, is another official who takes strong exception to what Schlesinger has been proposing. To elevate sharply the place of the RSSF in the ERDA waste management program would suggest a "clear lack of confidence in the viability of the geologic disposal concept," Bishop says. And, given such a lack of confidence, the NRC would be "put in the logically awkward position of being asked to license reactors that will produce wastes without assurance that the wastes can and will be disposed of safely," he adds.

This question as to whether and how the ERDA plan for waste repositories will be changed must be decided soon, but, at last report it was still very much up in the air.

Another major unresolved policy question is, quite obviously, what to do about the military wastes. Seamans says that the military as well as commercial waste must be put in deep geologic isolation because they both pose essentially the same hazards for the human environment. And, in truth, any who would deal with them differently will not find it easy to explain why. As Terry Lash observes, "If we are going to put the commercial wastes several thousand feet underground, how can we possibly justify leaving the military wastes 20 feet underground?"

Nevertheless, it is apparent from various ERDA documents that because of the extraordinarily high cost of retrieving and solidifying the high-level waste for geologic disposal, ERDA continues to regard tank storage as an active option for the long term.

The "technical alternatives" documents that ERDA plans to issue this year on management of the military wastes could represent a first step at least in addressing this long-deferred military waste problem. And the issues may be sharpened by the new lawsuit that NRDC has brought to force ERDA to seek an NRC license for 20 new carbon-steel waste storage tanks that it now plans to build at a cost of nearly a quarter of a billion dollars.

Whether fuel reprocessing and the recycling of plutonium are to be allowed is also a key policy question bearing upon waste management. The case for reprocessing rests on the fact that, while it could only extend the life of the light water reactor program for one or two decades, it would be a mainstay of the breeder reactor program on which all hope of nuclear power becoming a major energy resource for the very long term depends. But the waste management problems associated with reprocessing, and especially the fact that large volumes of transuranic wastes would be generated, are significant and must be considered along with reprocessing's more celebrated drawbacks, namely the hazards associated with plutonium theft or diversion.

Still another policy issue that needs addressing is whether waste management will ever really receive the consideration it is due so long as it remains under ERDA, which gave this problem a low priority in the past and may do so again sometime in the future. Mason Willrich, a University of Virginia law professor who has written extensively on nuclear issues, recently suggested in a contract study done for ERDA that a special waste management corporation be chartered by the government.

One reason why it is important for the United States to get on top of its nuclear waste problem is that a number of other nations, especially in the Third World, will almost certainly need American help

(Continued on page 704)

Microsurgery of Cataract, Vitreous, and Astigmatism. Proceedings of a symposium, London, June 1974. Dermot Pierse, H. Jonathan Kersley, and Sheila Tant, Eds. Karger, Basel, 1976. xiv, 270 pp., illus. $74.50. Advances in Ophthalmology, vol. 33.

A Minor Miracle. An Informal History of the National Science Foundation. Milton Lomask. National Science Foundation, Washington, D.C., 1976 (available from the Superintendent of Documents, Washington, D.C.). x, 286 pp. Paper, $2.75.

Modern Methods of Chemical Analysis. Robert L. Pecsok, L. Donald Shields, Thomas Cairns, and Ian G. McWilliam. Wiley, New York, ed. 2, 1976. xviii, 574 pp., illus. $16.95. *To order this book circle No. 421 on Readers' Service Card.*

Molecular Fluids. Fluides Moléculaires. Proceedings of a school, Grenoble, France, Aug. 1973. R. Balian and G. Weill, Eds. Gordon and Breach, New York, 1976. xvi, 460 pp., illus. $48.

Morphologische Studien im Bereiche der Pyrrhophyta. Das Problem Form und Selektion. Anton Böhm. Cramer (Gantner), Vaduz, Liechtenstein, 1976. 120 pp., illus. Paper, DM 50. Bibliotheca Phycologica, Band 22.

Osmosis and Tensile Solvent. H. T. Hammel and P. F. Scholander. Springer-Verlag, New York, 1976. xii, 136 pp., illus. Paper, $9.90. *To order this book circle No. 422 on Readers' Service Card.*

Physical Activity and Coronary Heart Disease. Papers from a symposium, Helsinki, Sept. 1975. Vesa Manninen and Pentti I. Halonen, Eds. Karger, Basel, 1976. x, 270 pp., illus. $50. Advances in Cardiology, vol. 18.

Plant Pathosystems. Raoul A. Robinson. Springer-Verlag, New York, 1976. x, 186 pp., illus. $19.70. Advanced Series in Agricultural Sciences 3. *To order this book circle No. 423 on Readers' Service Card.*

Practical Logic. Zygmunt Ziembiński. Translated from the Polish edition (Warsaw, 1973). Appendix on Deontic Logic by Zdzislaw Ziemba. Reidel, Boston, and PWN (Polish Scientific Publishers), Warsaw, 1976. xvi, 438 pp. $29. *To order this book circle No. 424 on Readers' Service Card.*

Principles of Cosmology and Gravitation. Michael Berry. Cambridge University Press, New York, 1976. x, 180 pp., illus. Cloth, $16.95; paper, $5.95.

Proceedings of the Conference on Environmental Modeling and Simulation. Cincinnati, Apr. 1976. U.S. Environmental Protection Agency, Washington, D.C., 1976 (available as PB257142 from the National Technical Information Service, Springfield, Va.). xiv, 850 pp., illus. $21.25.

Process Simulation. W. Fred Ramirez. Lexington (Heath), Lexington, Mass., 1976. xxx, 268 pp., illus. $24.95.

Progress in Nucleic Acid Research and Molecular Biology. Vol. 18. Waldo E. Cohn, Ed. Academic Press, New York, 1976. xii, 340 pp., illus. $29.50.

Progress in Theoretical Biology. Vol. 4. Robert Rosen and Fred M. Snell, Eds. Academic Press, New York, 1976. xii, 298 pp., illus. $31.50.

Seismic Modeling of the Earth's Crust. I. N. Galkin. Translated from the Russian edition (Moscow, 1972). Israel Program for Scientific Translations, Jerusalem, 1975 (U.S. distributor, Halsted [Wiley], New York). iv, 152 pp., illus. $18.50. *To order this book circle No. 425 on Readers' Service Card.*

The Selfish Gene. Richard Dawkins. Oxford University Press, New York, 1976. xvi, 224 pp. $8.95.

Simulation of Water Use and Herbage Growth in Arid Regions. H. van Keulen. Centre for Agricultural Publishing and Documentation, Wageningen, 1975 (U.S. distributor, International Scholarly Book Services, Forest Grove, Ore.). viii, 176 pp., illus. Paper, $13.50.

Soil Information Systems. Proceedings of a meeting, Wageningen, Netherlands, Sept. 1975. Stein W. Bie, Ed. Centre for Agricultural Publishing and Documentation, Wageningen, 1975 (U.S. distributor, International Scholarly Book Services, Forest Grove, Ore.). vi, 88 pp., illus. Paper, $7.50.

Solid State Diffusion. J. P. Stark. Wiley-Interscience, New York, 1976. xiv, 238 pp. $17.50. *To order this book circle No. 426 on Readers' Service Card.*

The Spaceflight Revolution. A Sociological Study. William Sims Bainbridge. Wiley-Interscience, New York, 1976. x, 294 pp. $16.95. Science, Culture, and Society. *To order this book circle No. 427 on Readers' Service Card.*

Spatial Analysis in Archaeology. Ian Hodder and Clive Orton. Cambridge University Press, New York, 1976. x, 270 pp., illus. $19.50. New Studies in Archaeology.

Stress and Strain. Basic Concepts of Continuum Mechanics for Geologists. W. D. Means. Springer-Verlag, New York, 1976. xii, 340 pp. Paper, $14.80.

The Survivalists. Patrick Rivers. Universe Books, New York, 1976. 224 pp. Cloth, $8.50; paper, $4.95.

Theoretical Ecology. Principles and Applications. Robert M. May, Ed. Saunders, Philadelphia, 1976. viii, 318 pp., illus. $13.50.

Theory of Metal Corrosion. V. V. Skorchelletti. Translated from the Russian edition (Leningrad, 1973). Israel Program for Scientific Translations, Jerusalem, 1976 (U.S. distributor, Halsted [Wiley], New York). vi, 238 pp., illus. $27. *To order this book circle No. 428 on Readers' Service Card.*

Trees and Bushes of Europe. Oleg Polunin. Drawings by Barbara Everard. Oxford University Press, New York, 1976. xvi, 208 pp. $11.50.

Trees and Man. Herbert L. Edlin. Columbia University Press, New York, 1976. xvi, 270 pp. + plates. $25.

Underwater California. Wheeler J. North, with sections on underwater photography by Robert Hollis. Illustrated by Laurence G. Jones. University of California Press, Berkeley, 1976. iv, 276 pp. + plates. Paper, $5.95.

Vascular Neuroeffector Mechanisms. Papers from a symposium, Odense, July 1975. J. A. Bevan, G. Burnstock, B. Johansson, and O. A. Nedergaard, Eds. Karger, Basel, 1976. viii, 260 pp., illus. $51.

Visual Display Units and Their Application. Derrick Grover, Ed. IPC Science and Technology Press, Guildford, Surrey, England, 1976. viii, 208 pp., illus. £7.

What Time Does. Klaus Wagn. Translated from the German edition (Munich, 1975) by Sophie Wilkins. Caann Verlag, Munich, 1976 (U.S. distributor, Associated Booksellers, Bridgeport, Conn.). 96 pp. $4.50.

Wind-Catchers. Americn Windmills of Yesterday and Tomorrow. Volta Torrey. Stephen Greene Press, Brattleboro, Vt., 1976. xii, 226 pp., illus. $12.95.

The World's Shells. A Guide for Collectors. S. Peter Dance. McGraw-Hill, New York, 1976. 192 pp., illus. $10.95.

NEWS AND COMMENT

(Continued from page 666)

in overcoming their own. In fact, waste management is a field in which international cooperation will be essential. The countries now developing a nuclear power industry vary in technical competence, territorial size, geology, and possibilities for disposing of nuclear wastes within their own boundaries. Because of such differences, an internationally run program for disposal of wastes beneath the deep seabed is considered possibly to hold the answer for many countries. As contributors to the work of the Organization for Economic Cooperation and Development's Nuclear Energy Agency, four of the major nuclear nations—the United States, the United Kingdon, France, and Japan—have begun a modest effort to establish a data base for the seabed disposal concept.

Should the United States, the nation that opened the nuclear era, fail over the next 10 to 15 years to set an example for safe and permanent disposal of radioactive wastes, its leaders will have themselves partly to blame if other nations do no better. And, as the U.S. experience of the past two decades has shown, in waste management to defer ultimate solutions is often to make them far more difficult and costly to achieve. Moreover, if the future growth of nuclear power does match the expectations of its advocates at home and abroad, the accumulation of wastes could become such as to make permanent disposal an illusory goal unless there is a steadfast commitment now to achieve it.

—LUTHER J. CARTER

RECENT DEATHS

C. Dale Beers, 75; professor emeritus of zoology, University of North Carolina, Chapel Hill; 23 September.

Henry H. Chisman, 67; professor emeritus of forestry, Pennsylvania State University; 30 September.

Frank A. Fatzinger, 51; professor of psychology, Western Michigan University; 17 September.

Raymond N. Keller, 67; professor emeritus of chemistry, University of Colorado; 21 September.

David F. Miller, 83; former chairman of zoology and entomology, Ohio State University; 23 September.

Walter C. Reusser, 84; professor emeritus of education, University of Wyoming; 22 September.