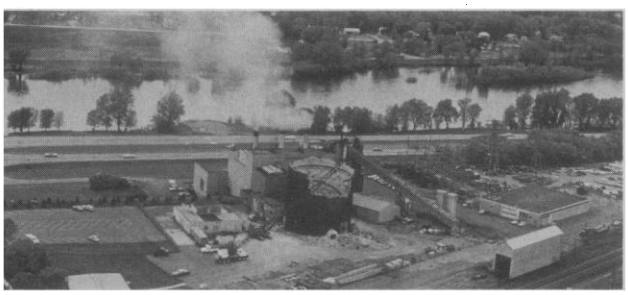
A Long-Term Problem for the Nuclear Industry

Worn-out reactors may remain radioactive too long to entomb; a student discovered what the experts missed

Twenty-four years ago, the Shippingport atomic power station began generating electricity at a site on the banks of the Ohio River in western Pennsylvania. As the world's first large commercial reactor, it was heralded as the vanguard of the nuclear age, a model for future power stations. In the next few years, Shippingport may provide a model of a different kind. It is scheduled to be shut down, cut up, and shipped piece by piece to a burial site, an operation that should provide a real test of the nuclear industry's ability to dispose safely of intensely radioactive facilities.



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A reactor meets its end

The 22-megawatt Elk River Reactor is the largest plant dismantled in the United States. The task took more than 2 years and cost $6.15 million.

Such a test will be important, for the industry will soon be faced with the problem of what to do with worn-out nuclear reactors. Although only a few reactors have so far been shut down, many of those built during the 1960's will reach the end of their working lives in the 1990's. Until recently, it was assumed that the cheapest solution would be to entomb a disused reactor in concrete until the radioactivity it contains declines to safe levels. But recent findings indicate that some components may remain radioactive for thousands of years (see box on page 377), and the Nuclear Regulatory Commission (NRC) may soon rule out permanent entombment as a viable option. Utilities may thus be forced to dismantle reactors soon after they take them out of service.

It will be a difficult task. According to estimates published by the Department of Energy (DOE), which owns the Shippingport reactor, it will cost more than $40 million at today's prices to tear the plant down and remove radioactive debris from the site. The process, which will take about 5 years to complete, will generate some 11,700 cubic meters of radioactive waste—almost as much as will be produced in the cleanup of the crippled Three Mile Island nuclear reactor. All this from a facility that is less than one-tenth the capacity of reactors being built today.

Recent estimates indicate that it would cost between $50 million and $100 million to decommission a 1200-megawatt power reactor. Although this represents less than 10 percent of the cost of building the plant, few utilities have made any financial arrangements for decommissioning, and there is so far no experience in tearing down a large radioactive reactor.

The problem of what to do with unwanted reactors and other radioactive facilities has only recently begun to attract public attention, thanks largely to concern over who will eventually pay the mounting costs of cleaning up Three Mile Island and decontaminating the disused reprocessing plant in West Valley, New York. With 78 reactors licensed for operation and another 77 with construction permits, the NRC is now getting around to drafting regulations governing how nuclear plants should be decommissioned and what financial arrangements should be made to ensure that sufficient funds are available to complete cleanup operations. NRC staff members have been working on the new regulations since 1978, and they are still at least a year from completing their work.

The radioactivity that remains in nuclear reactors long after they are shut down and the fuel elements are removed comes from two chief sources. First, isotopes enter the cooling water from leaking fuel rods and, together with radioactive corrosion products, they are deposited on the internal surfaces of pipes and other components. And second, some radioactive isotopes are formed in steel structures and concrete shields close to the reactor core when atoms of trace elements are bombarded with neutrons.

When a utility shuts down a reactor at the end of its useful life, it is thus faced with the problem of keeping these intensely radioactive materials out of the environment. At present, it has three options:

- *Dismantlement.* Soon after shutdown, the fuel elements are removed, pipes and other internal components are flushed with cleaning fluids, radioactive steel and concrete structures are cut up by remotely controlled cutting and blasting equipment, and all radioactive debris is shipped to a burial site for disposal.
- *Safe storage.* Fuel is unloaded from the reactor, liquids are removed, and the system is flushed out. The plant is then placed under constant guard to prevent public access for 30 to 100 years. This allows sufficient time for most short-lived isotopes to decay, and the plant is then dismantled and parts containing residual radioactivity are shipped to a low-level burial site.
- *Entombment.* This is the same as safe storage, except that after the reactor is decontaminated it is encased in a concrete structure designed to prevent any access and to contain the radioactivity. The concrete tomb greatly reduces the need for surveillance and, consequently, the cost of looking after the plant. Until recently, entombment was looked upon as a permanent solution—the reactor would simply remain in its concrete case until all the radioactivity has decayed to safe levels.

Technical and economic considerations are beginning to favor immediate dismantlement as the preferred option—at least in the eyes of key staff members of the NRC. "The more we see of it, the more we think the thing to do is to encourage dismantlement," says Donald Calkins, the man in charge of drawing up NRC's new policy on decommissioning.

Permanent entombment, which has long been favored by the utilities, may have to be ruled out because of recent findings that some reactor components

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will contain very long lived isotopes of nickel and niobium. These will remain radioactive for thousands of years, well beyond the life of any conceivable entombment structure. Thus, there could be no guarantee that radioactive products would not eventually enter the environment from an entombed reactor.

Long-term storage is also frowned upon because, says Calkins, "one of the major problems is that nobody knows what the plant is like any more." The

Isotopes the Nuclear Industry Overlooked

The problem of what to do with worn-out nuclear power plants has taken on an important new dimension in the past few years, as evidence has come to light that some reactor components may remain radioactive for thousands of years after a plant is shut down. The conventional wisdom had previously been that radiation levels would decline to insignificance after several decades.

The culprits are very long lived isotopes of nickel and niobium, which are formed as the result of bombardment by neutrons. The formation of these isotopes was overlooked by the nuclear industry until the late 1970's, when the problem was brought to public attention largely as the result of work by undergraduate students.

Their discovery may have an important impact on regulations governing the decommissioning of nuclear plants. In particular, the Nuclear Regulatory Commission (NRC) may forbid utilities to entomb reactors in concrete and leave them in place—an option that was long considered the cheapest way of dealing with the problem. Instead, the NRC staff is considering requiring that reactors be dismantled relatively soon after they are shut down and that the radioactive waste be shipped to a disposal site (see accompanying story). Components containing the long-lived isotopes may even have to be consigned to a geologic repository when one is eventually established.

When a reactor is first shut down, the pressure vessel and other components close to the core are intensely radioactive, largely because of the presence of cobalt-60. This isotope is formed when atoms of cobalt, a constituent of most steels, are hit by neutrons from fission reactions in the reactor fuel. Because cobalt-60 has a half-life of 5.27 years, the radioactivity diminishes relatively quickly. After a century, the amount of cobalt-60 will have dropped by a factor of about one million.

Although it has always been known that isotopes of other elements would be formed by neutron bombardment, it was thought that they would be present in such tiny quantities that they would contribute negligible amounts of radioactivity. Thus, once the cobalt-60 had decayed, the reactor components would be relatively harmless. In February 1976, however, Marvin Resnikoff, a physicist then on the staff of the New York Public Interest Research Group, went public with calculations indicating that nickel-59 may pose a long-term radiation problem.

Resnikoff says that he and four undergraduate students realized that nickel-59 may cause difficulties when they looked at data on the dismantling of the Elk River reactor, a small power plant in Minnesota that was shut down in 1968 after only 4 years of operation. Although only trace amounts of nickel-59 were present in Elk River components, Resnikoff calculated that significant quantities would be formed in a large power reactor during 30 years of operation.

Nickel-59 is potentially important because, although it contributes only a tiny fraction of the radiation inventory when a reactor is shut down, it has a half-life of about 80,000 years. It will therefore be around long after cobalt-60 has decayed to insignificance, giving off radiation well above permitted levels.

Resnikoff recalls that he was initially anxious about releasing his calculations because "they went against the whole mindset at the time." The nuclear industry was then saying that if a reactor is entombed for 180 years, it will cool down to a safe level, he pointed out. Nevertheless, he published a press release challenging the industry's plans. Resnikoff says that his calculations were vigorously attacked by the industry, but most studies since then have acknowledged the problem with nickel-59. "It is an example of what happens when you have thousands of engineers all moving in one direction, and a handful of outside critics takes a look at their work," Resnikoff claims.

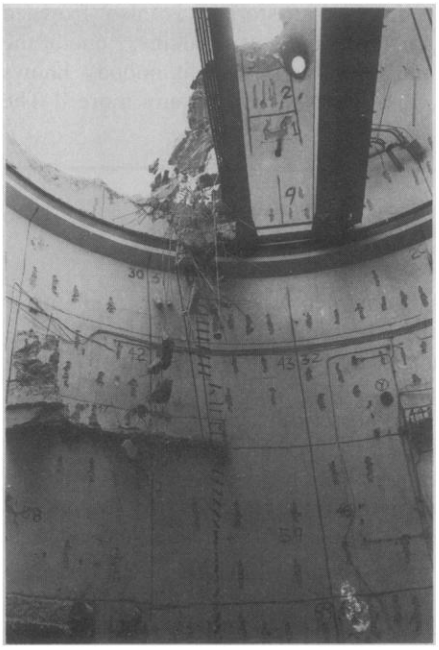
A year later, a second long-lived isotope, niobium-94, was identified as a potential problem in irradiated reactor components. Again, the discovery came from researchers outside the nuclear industry.

Robert Pohl, a professor of physics at Cornell University, said that he decided, in the light of Resnikoff's findings, to see whether there are any hazardous activation products among trace elements in steel. An undergraduate student, John Stephens, looked through data on radioactive isotopes and flagged niobium-94 as a potential problem. It decays with a half-life of 20,300 years, emitting very energetic gamma rays. A literature search indicated that niobium is added to some steels to inhibit cracking, and that it is a trace constituent in stainless steel. Pohl and Stephens published their findings in *Nuclear Engineering and Design* in 1978.

"Nobody in the nuclear business knew of the problem at the time," says Pohl. It is now generally accepted, however. A 1980 report by Battelle Pacific Northwest Laboratories indicates, for example, that the decay of niobium-94 will dominate the radiation dose rate from irradiated steel about 70 years after a reactor is shut down.

An environmental impact statement on reactor decommissioning, published last year by the NRC, indicates that the dose rate from niobium-94 in reactor components will be about 17,000 rems per year if the reactor is operated for 30 to 40 years. That from nickel-59 will be about 800 rems per year. "These dose levels are substantially above acceptable residual radioactivity levels," the statement notes. Entombing a disused reactor in concrete would thus be acceptable only if the long-lived isotopes were removed or if the integrity of the entombing structure could be maintained for thousands of years, the study concludes.

After the problems with nickel-59 and niobium-94 were discovered, the NRC commissioned a study to see whether any other potential activation products may cause trouble. "So far, we haven't identified any on the scale of those two," says Donald Calkins, NRC's manager of decommissioning programs.—COLIN NORMAN



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View from the core

Inside the partially demolished Elk River Reactor containment dome.

lack of records, especially of alterations to the original plant design, are "a really tremendous problem—experience to date has been terrible," he says. At the very least, Calkins suggests, the NRC is likely to call for greatly improved archival records to facilitate delayed dismantlement of power plants.

There may, moreover, be a good reason why the utilities might come round to Calkins' point of view. It may actually be cheaper to tear down a reactor soon after it is shut down than to wait for a few decades.

According to a major study by the Battelle Pacific Northwest Laboratories, it would cost $43.6 million (in 1978 dollars) to dismantle a 1200-megawatt reactor soon after it is shut down. Safe storage for 30 years followed by dismantlement would cost $58.9 million, even though the radiation levels would have declined substantially during storage. Permanent entombment would cost $40.6 million, the Battelle study concluded. DOE's estimates for various alternative means of decommissioning the Shippingport reactor also indicate that immediate dismantlement is the cheapest route. The reason is simple: although it is cheaper to tear a reactor down once radiation levels have declined, the savings are outweighed by the cost of guarding and maintaining the facility for several decades.

Dismantling a large, intensely radioactive nuclear reactor would be a formidable task, but industry and NRC officials alike are confident that it could be done with technology that has already been developed. "There is no doubt in my mind that with proper shielding and proper handling, it could be done safely," says David Greenwood of the Stone and Webster Engineering Corporation. Greenwood was a member of a panel that recently looked into decommissioning for the Atomic Industrial Forum (AIF).

Such confidence is based on recent experience in dismantling two relatively tiny reactors, the Elk River plant in Minnesota and the Sodium Reactor Experiment in Santa Susana, California. Both were shut down after only a few years of operation, and they were taken apart and buried at a cost of $6.15 million and $10 million, respectively.

In each case, most of the intensely radioactive steel components were cut up underwater with a specially developed plasma torch operated by remote control. At the end of the operation, the cranes and cutting equipment were themselves taken apart and buried.

Experience with these two reactors has provided a taste of the problems encountered in a very harsh radiation environment. The anticipated dismantling of the Shippingport reactor should provide a more realistic test of what it will be like to tear down a major power plant. For one thing, by the time it is shut down at the end of this year, Shippingport will have been in operation on and off for a quarter of a century. And for another, it has many of the design features of today's reactors, including a 9-inch-thick steel pressure vessel. (One possibility DOE is studying, however, is to remove the pressure vessel and transport it intact by barge to a burial site.) So far, DOE has not made a final decision on whether to dismantle Shippingport immediately after it is closed down, or whether to wait until some of the short-lived radioactivity has cooled down. An environmental impact statement published late last year strongly favors the former alternative, however.

Even if experience with Shippingport does prove that the technology for dealing with a large power reactor is in place, it is clear that some major problems would remain. Not the least of them is the immense volume of radioactive material that would have to be disposed of. According to the Battelle studies, about 18,000 cubic meters of contaminated steel and concrete would be generated in the dismantling of a 1200-megawatt reactor. That is about one-fourth the volume of low-level wastes now generated annually in the United States. Voters in Washington State and South Carolina, where the nation's two existing commercial burial sites are located, are already anxious to prevent their states being used as nuclear dumping grounds for the rest of the country. Thus it is unlikely that any large reactor will be torn down until there is a resolution of the waste storage problem. (This problem does not arise with the Shippingport reactor because it is a government-owned facility, and its wastes would therefore be buried in a military site.)

Partly for these reasons, the utility industry would vigorously oppose NRC regulations requiring prompt decommissioning of power reactors. "The industry, to a degree, feels that such a policy is premature," says Donald Blackmon of Duke Power Company, who chaired the AIF's task force on decommissioning. The utilities, moreover, are not yet willing to concede that permanent entombment should be ruled out because of the presence of long-lived radioactive isotopes. "There is no evidence that the overall impact to the general public is less with immediate dismantlement than with entombment," argues Blackmon. Since no permanent geologic repository has yet been established for long-lived waste products, he points out that entombing them in a reactor may actually be less harmful than burying them in a low-level waste dump.

The industry's objections to NRC's evolving policy on dismantling versus entombment are relatively muted compared with its objections to another suggestion made by NRC staff—that the federal government should require utilities operating nuclear reactors to establish a segregated fund for decommissioning, and that the fund should be administered by a third party such as a state agency.

Current NRC regulations simply require reactor owners to demonstrate that they have the financial means to operate and safely close down a nuclear plant. But NRC may require that assurance to be made more explicit, in the form of hard cash. According to Calkins, two proposals are under consideration. A utility would either have to pay the entire estimated decommissioning costs into a special fund before a reactor is brought into operation, or it would have to pay into a fund during the lifetime of the plant. The second option would only be acceptable if a utility has sufficient insurance to cover decommissioning if a plant is shut down prematurely.

Such arrangements would ensure that the costs of decommissioning are paid by those who benefit from the electricity rather than by future generations. They would also guard against the possibility of the general public being forced to pay cleanup costs when a utility lacks the means to do so, which may be the case with the Three Mile Island accident.

The utilities, however, would prefer a more flexible arrangement, in which the states are given the chief responsibility for ensuring that adequate financial provisions are made for decommissioning. The states may, however, be no more lenient than the NRC. Bills have already been introduced in several legislatures that would require utilities to establish decommissioning funds over which they would have no control.

Although the age of commercial nuclear power is already a quarter century old, the problem of what to do with worn-out reactors has not yet become critical. Only four reactors are currently potential candidates for decommissioning (Humboldt Bay in California, Dresden in Michigan, Indian Point I in New York, and Three Mile Island in Pennsylvania). So far, the utilities have been happy to let the federal government pave the way by dismantling disused DOE reactors. But a combination of new regulations and the impending retirement of the first generation of commerical power reactors could soon force the industry to take the plunge into the demolition business.—COLIN NORMAN

Rehnquist's Drug Dependence Poses Dilemma

How broad is the right of privacy during detoxification if the patient is a Justice of the Supreme Court?

It is not entirely clear how Supreme Court Justice William Rehnquist developed a dependence on a common sedative, but it is clear that his habit was serious enough to require a medically managed program of detoxification. The therapy was directed by Hugo Rizzoli, chief neurosurgeon at the George Washington University Hospital in Washington, D.C.

This news, which reached the press on New Year's Day, created a dilemma for hospital officials. They felt trapped between their obligation to let the public know what was happening to an important government figure and their duty as physicians to guard the patient's privacy. As a result, they said very little. The record of events remains cloudy, with the prospects for Rehnquist's recovery and future performance on the Court not well defined.

Neither Rehnquist nor Rizzoli will speak to the press about the case. Questions have been referred to hospital spokesman Dennis O'Leary, the physician who spoke before the cameras when President Reagan was being treated in the same hospital for bullet wounds received in the assassination attempt.

O'Leary describes Rehnquist's problem essentially as back pain, with complications. He says that Rehnquist came to Rizzoli sometime in December complaining of pain. He had been referred by his own physician. Rizzoli's staff soon learned that Rehnquist had been taking large doses of a tranquilizing drug, and they recommended that the dose be curtailed. O'Leary says that the Justice has suffered from "degenerative lumbar disc disease" for many years, enduring a chronic backache that waxes and wanes in severity. Rehnquist's personal physician, who has not been identified, apparently prescribed a sedative during one of the periods of waxing pain.

O'Leary declines to name the drug, other than to say that it is not narcotic. The reason for reticence, he adds, is that "We were pretty specific about drug names last spring when the President was here," and "some of the drug companies used that information for purposes other than we had intended."

After the drug use was curtailed at Rizzoli's direction, Rehnquist began to experience more pain. On 27 December he was admitted to the hospital, ostensibly for treatment of his back. On 30 December the drug withdrawal symptoms became so intense, as O'Leary told one reporter, that Rehnquist suffered "disturbances in mental clarity" and "distorted" perceptions of reality. The hospital staff decided to resume administering the sedative. Rehnquist was sent home several days later, on 3 January, with pain-killing medication and a quantity of the mystery sedative to be taken in smaller doses. He was placed on a sort of maintenance therapy, and returned to work on 6 January.

Speculation about the mystery drug focused on two likely candidates: Valium, a mild tranquilizer considered to be a muscle relaxant in heavy doses, and Placidyl, a strong sleep medicine or hypnotic. O'Leary will not say which drug is causing the problem, but neither does he deny the *New York Times'* report that it is Placidyl.

A brief survey of professional opinion revealed that there is no consensus about the wisdom of using sedatives like these for treating back pain. Nevertheless, it is agreed that these are potent, habit-forming chemicals which can have serious side effects. The 1981 *Physicians' Desk Reference* (*PDR*) for prescription drugs says that Placidyl is meant to be administered for no longer than 1 week for the short-term control of insomnia. After a week, the *PDR* notes, a patient should be asked to go without the drug for at least a week and should undergo "further evaluation" before being given a new prescription. (O'Leary says that Rehnquist was using his sedative for at least 2 weeks.) The *PDR* gives this warning in bold type: "Prolonged use of Placidyl may result in tolerance and psychological and physical dependence. Prolonged administration of the drug is not recommended."

Some of the symptoms of Placidyl intoxication, according to the *PDR*, are incoordination, tremors, confusion, slurred speech, and muscle weakness. Withdrawal symptoms, which may appear as late as 9 days after use of the drug has stopped, include delirium, schizoid reactions, perceptual distortions, memory loss, slurring of speech, unusual anxiety, and other signs of agitation. To treat a patient who has become dependent on Placidyl, the *PDR* says, one should administer a dose roughly equal to the dose used during the period of intoxication. "A gradual stepwise reduction of dosage may then be made over a period of days or weeks."

Although none of the neurosurgeons

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