## CHAPTER TWENTY-THREE

# THE ENDOWMENT OF URANIUM

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*The growth in the world's inventory of plutonium can be brought to a halt and then reversed.*

–Till, Chang, and Hannum, 1997–

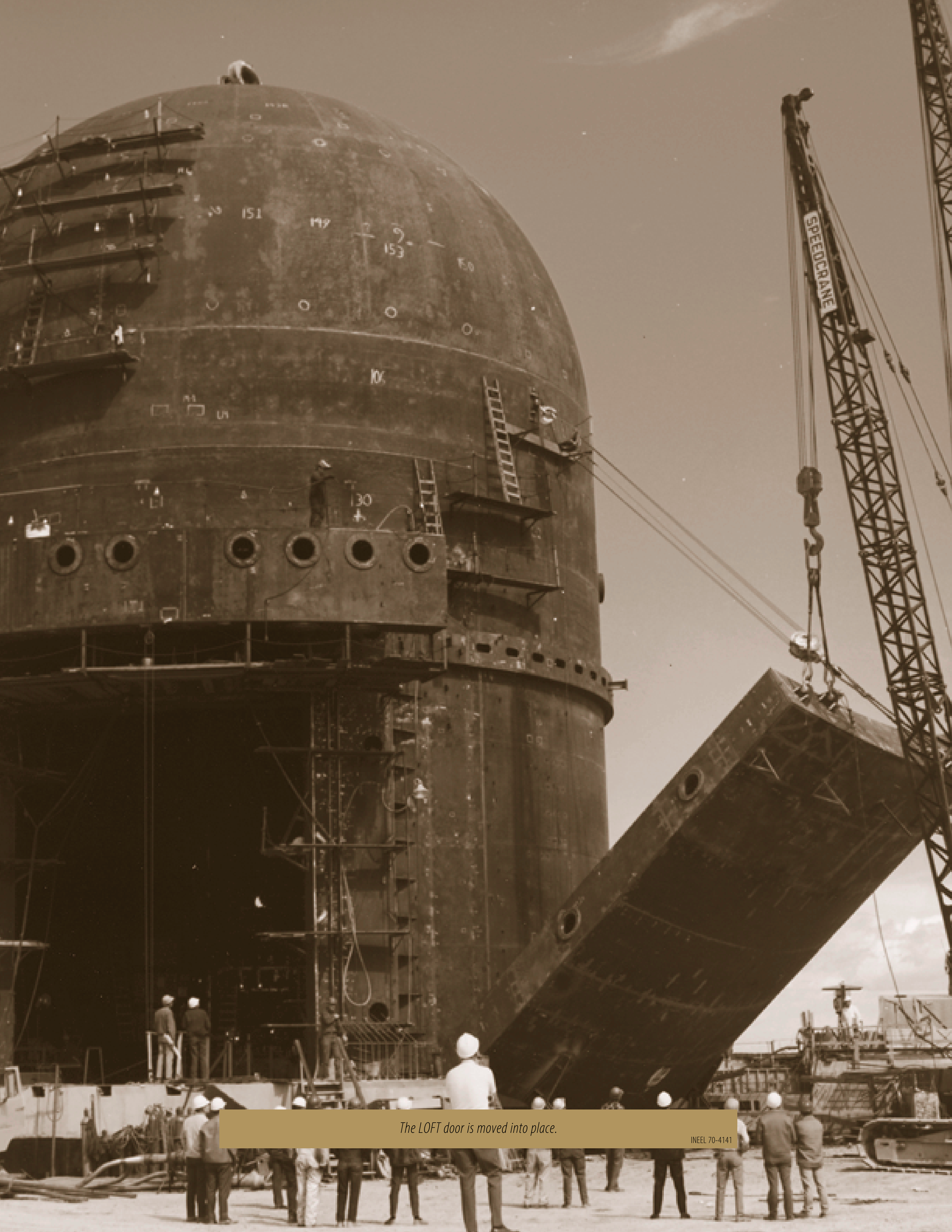
As Site employees began to get used to their new name in 1974, the national reactor safety testing program, which included LOFT, PBF, Semiscale, and other INEL projects, finally emerged from the policy chaos of the previous ten years. Early in her term as AEC chair, Dixy Lee Ray had created a new Division of Reactor Safety Research in the AEC. She removed safety research from the control of Milton Shaw. Shaw then left the AEC. Around the Site (and at other AEC facilities), this development produced either general rejoicing or, among those who had admired his tenacity and hard-nosed management approach, a sense of regret.[1]

Allocations for safety research improved immediately, and the LOFT program picked up steam. During the lean years, the Phillips and Aerojet teams had barely kept the project grinding forward. Once it became clear that the mission of the reactor would include repeated LOCA experiments, the designers had to re-engineer a complex water-management system and a special holding tank (the blowdown vessel) so that the reactor could "lose" its cooling water without flooding the reactor chamber or causing other damage to the test facility. Solving this problem had created extra costs. When rigorous specifications resulted in no bids from vendors for main coolant pumps and valves, LOFT project engineers scrounged these items from *NS Savannah,* the nation's first and only nuclear-powered merchant ship. Launched in 1961, it had been decommissioned and was about to be scrapped. Other LOFT parts came from as far away as a United States Air Force base in Vietnam. Site craft shops proceeded to modify and polish the hand-me-downs for the LOFT plant.[2]


INEEL 73-3710

LOFT reactor being moved into containment vessel.

Another implication of repeated experiments was that the reactor might require detailed examination after each test. This could be done in the TAN Hot Shop. The engineers decided to recycle the same equipment and use the same method that the ANP had used to move its reactor experiments back and forth. The four-rail track and the shielded locomotive were pressed once more into service. If the reactor was to leave the containment building, the building would need a very large, very heavy door. Before each test the door would have to be well-sealed to retain potential contamination inside the building. The 200-ton door had been installed in November



*The LOFT door is moved into place.*

INEEL 70-4141

1970. As it turned out, operators did not remove the reactor after the tests because of the complexity of auxiliary piping and other systems around the reactor. But they did open the door between tests to facilitate preparations for the next test.[3]

LOFT engineers—the ones at the Rogers Hotel—had created computer models predicting how different types of emergency core cooling systems would supposedly perform if a reactor lost its coolant. Some systems pumped new cooling water into the core; others injected cooling water from pressurized tanks. The purpose of the LOFT experiments was to provide empirical validation—or not—for the theory behind the computer models.[4]

The first nuclear test on December 10, 1978, imitated a "double-ended guillotine break," where the coolant flooded from both ends of a broken pipe. This was presumed to be among the worst kinds of accidents. The computer model had predicted that the fuel temperature could rise to 1,350°F and that the emergency system would restore cooling water within 90 seconds. The computer proved to be conservative. The coolant was restored within 44 seconds, and the maximum temperature of the fuel rose to about 1,000°F. More tests were planned to imitate other accidents, but the assessment of what kinds of breaks to test was about to change.[5]

On March 28, 1979, at the Three Mile Island 2 (TMI) nuclear power plant near Harrisburg, Pennsylvania, the main pumps circulating the secondary coolant stopped running. This prevented heat removal from the primary cooling system. The turbine shut down, and the reactor likewise. Decay heat continued to heat the water near the core. This caused a pressure surge and forced open a pressure relief valve. Emergency pumps began to restore circulation. As pressure subsided, the pressure relief valve should have closed, but it stayed open.


INEEL 79-9362

*Three Mile Island Nuclear Station in 1979.*

The operators didn't know, couldn't see, and hadn't been trained to imagine that the valve was open. Because of other events and faulty indicators, they believed too much water was entering the vessel and shut down the emergency pumps. They started, then stopped the primary coolant circulating pumps. Water pressure fell, and some of the water in the pressure vessel flashed to steam. One thing after another went wrong with instruments, equipment, computers, and human judgment. During the next sixteen hours, a third of the core melted, although no one knew what this fraction was until much later. The hot core material did not melt through the reactor vessel, let alone down to China. About twenty curies of radioiodine were released to the environment.[6]

In the immediate effort to understand the condition of the reactor, inspectors from the NRC arrived from Washington, D.C., and concluded that the zirconium-clad metal was interacting chemically with the hot steam to create hydrogen gas. They feared that a bubble of the gas could interfere with the flow of cooling water through the core. Analysts speculated that a large gas bubble could explode and blow open the containment shell.[7]

Urgent questions about the hydrogen came to INEL scientists. Within twenty-four hours, they had modified the piping at the Semiscale facility to represent the situation at TMI and delivered reassuring information about the hydrogen bubble. Fear of an explosion lifted. President Carter visited the TMI plant for a briefing on the condition of the facility, a gesture that soothed the country and calmed Harrisburg citizens. A support team flew from INEL to

Pennsylvania and became part of the effort to secure the plant in a cold shutdown position.[8]

But the hard-slogging work of investigation was just beginning. How could the place be cleaned up enough to start analyzing what had taken place inside the reactor? What exactly had happened to the fuel elements inside the reactor vessel? Where had all the fission products gone after the fuel-rod cladding had burst or melted?

The PBF reactor at INEL had been designed to continue the tradition of SPERT in testing the performance of fuel elements during transients, or sudden bursts of power and heat. But it could handle a far larger repertoire of simulated accident scenarios than could SPERT. By this time, the many varieties of imagined accidents had acquired highly specific names and acronyms: reactivity-initiated accidents (RIA), power-cooling-mismatch (PCM) accidents, anticipated transients without scram (ATWS), loss-of-coolant accidents (LOCA), and severe fuel damage (SFD) accidents. During each accident simulation, sophisticated instruments recorded temperatures of fuel, of cladding, of coolant; the building pressure inside the fuel rods; the change in shape of fuel rods during the event. Monitors detected and timed the precise movement of fission products as they escaped from a fuel rod whose cladding had failed. As usual, PBF tests took place only after a computer program had predicted the results of the test. Constant refinement—and post-test examination of melted and mangled fuel rods in a hot cell—brought predictions and actual results into closer and closer agreement.[9] Now the TMI operators wanted to know the shape and condition of the fuel inside their damaged pressure vessel. After the PBF had run simulations of the TMI accident, INEL scientists took the test bundle, still in its container vessel, to Argonne-West's Neutron Radiography (NRAD) reactor and made neutron radiographs of the core. The images showed a combination of melted fuel and a mass of rubble collapsed at the bottom. Beverly Cook was one of the INEL engineers to take the news to TMI.

*We made slides of the images for a presentation to the people in Pennsylvania and flew out there. They still had not seen the inside of the TMI vessel. Using the PBF simulation, we told them what their core would look like. We showed them zones of melted fuel and how they would lay over rubble at the bottom. They didn't believe it. They couldn't believe that so much of their core had melted. But we knew that the uranium oxide in the fuel had interacted with other metals and caused more melting than they thought.*

*Later, when the TMI core was opened up for the remote insertion of cameras, we watched the procedure as it unfolded on a videotape. The camera went in from the top and was gradually sent further and further into the vessel. No one had edited the remarks of the camera operators as they were doing this, and we heard them say in amazement, "Where's the core?" and other deletable expletives. They weren't finding anything at all at the top of the vessel, just foot after foot of empty space. When they finally got a look at it, the core lay pretty much exactly as we had predicted.*[10]

The connection between INEL and TMI continued in many forms. INEL teams developed training and emergency response techniques for TMI accident scenarios, many of which had been learned because of the post-TMI investigation and the Semiscale tests. Later, INEL scientists helped evaluate the condition of the TMI fuel. INEL transportation managers arranged the highly complicated task of packaging the fuel and other core debris for a trip to Idaho for further examination and temporary storage.[11]

The purpose in bringing the fuel to the INEL was to determine what had taken place in the core during the accident. What was below the rubble bed and its solidified sublayer? INEL specialists designed and built a 20,000-pound "core bore" machine in the thirty months after the accident and took it to TMI. Adapted from a commercial drilling machine, it had to fit through an air lock and operate remotely. The drill bits bit through ceramic and metal to reach the interior of the reactor vessel. After a hole was drilled, a remotely operated television camera inspected the interior of the core. With these techniques the scientists mapped the core, learned where the fission products were located, and developed a plan to ship the materials safely to Idaho for further examination and temporary storage. The last shipment of TMI debris arrived in Idaho in 1990 and the fuel examination program continued for several years.[12]

After this real accident, which had involved a "small" leak caused by the stuck pressure-relief valve, the focus of LOFT and Semiscale experiments shifted to investigating small leaks and a variety of operational transients and accident scenarios associated with them. Whereas PBF had focused on fuel behavior during the accident, LOFT tests focused on the cooling water. By December 1980, LOFT managers had designed a series of tests to simulate the TMI accident and verify predictive computer codes. Taken as a whole, these tests persuaded former doubters that INEL safety test results could be scaled to commercial-sized power plants. One of the tests successfully duplicated an incident that had occurred at an Arkansas power plant.[13]

The INEL test programs attracted worldwide interest. At first financed by the NRC, sponsorship shifted to the international Organization of Economic Cooperation and Development in January 1983, which contributed to a $93 million test program that continued from 1983 to 1986. The nuclear tests concluded in July 1985 with a deliberate melting of the LOFT reactor's test-fuel bundle, somewhat fulfilling LOFT's original destiny as a "meltdown" reactor. One purpose of the test, aside from comparing actual results with the predicted results, was to trace the path of fission products released in the melt. The results suggested that a failure of the containment vessel was not likely to create nearly the radioactive exposures to the public as the most extreme, but theoretical, scenarios had imagined.[14]

Because of the PBF, LOFT, Semiscale, and other safety testing facilities—a Two-Phase Flow Loop, for example, which examined in minute detail the relationships between steam and water during an accident—the INEL had acquired a global reputation as the best technical source of data about the behavior of pressurized-water nuclear power plants during an accident. The INEL found that its advanced computer codes, simulators, instrumentation labs, damage analysis capabilities, risk evaluation techniques, and training methods continued to be in demand.[15]

Since the very beginning of the commercial nuclear power industry, the engineers and scientists at the INEL had been among the strong proponents of the idea that the nation's nuclear power plants must operate with an impeccable safety record. They had felt that their work could make important contributions to the safe design and operation of these plants. At times, they had met with resistance in Washington along the way by those who felt that commercial plants already had adequate safety designs. In the end, the nuclear reactor safety codes designed and proved at INEL, known by such names as RELAP5, TRAC-BD1, and FRAPCON, were in widespread use by the nuclear industry that initially had been so skeptical.[16]

By the time LOFT ran its simulation of the TMI accident in 1985, the course of nuclear research at the Site was rapidly diminishing. The SPERT series of experiments had ended in 1970, and PBF went on standby status in 1985. At the Test Reactor Area, the ETR joined the MTR in retirement in 1981, leaving only the ATR to serve the Navy fuel examination and materials testing programs. Computer power had displaced many types of experiments formerly accomplished with the help of low-power and test reactors.[17]

The only corner at INEL engaged in the development of new reactor concepts was Argonne-West. Ronald Reagan's election in 1980 brought fresh political support for the nation's nuclear enterprise, despite a wave of doubt arising from many citizens after the TMI accident. Reagan supported the continued commercial development of nuclear power. He wanted the breeder reactor to move toward its destiny as a safe, economically viable solution to energy shortages. At Hanford, the FFTF went critical for the first time in 1980 and reached full power in 1982. Supporting it, EBR-II had earlier been transformed into a materials testing reactor, irradiating candidate fuels and doing related safety testing.

Reagan urged Congress to continue to support the construction of a large demonstration plant at Clinch River, Tennessee. This project was to be financed by the joint effort of DOE and contributions from more than seven hundred utility companies. The project would finally, it was hoped, demonstrate the commercial feasibility and safety of the Liquid Metal Fast Breeder Reactor (LMFBR). In its beginning, the concept promised to breed plutonium fuel at a rate to double the initial fuel loading in eight to ten years of operation.[18]

The impact of Ronald Reagan's presidency was felt in a number of other ways at the Site. In 1983 Reagan undertook the Strategic Defense Initiative (SDI), a research and development program to devise a defense against intercontinental ballistic missiles. More than the breeder program, the SDI offered opportunities to expand the INEL. The

Idaho nuclear boosters went to work, crippled as they were by a governor distracted by an injection well and the "green" protest network. Now that funds were flowing for defense projects, supporters hoped that INEL expertise could attract some of it. Although they had tried and failed some years earlier to land the (Clinch River) breeder in Idaho, this time they had some success.[19]

Idaho's major asset in Washington was now Senator James McClure. With the help of his advocacy, DOE selected the INEL as the site of a New Production Reactor (NPR) to manufacture tritium replenishment for the warheads on Pershing II, Trident, and Cruise missiles. A spokesperson for the Snake River Alliance asserted that "the people can stop it" and promised to be vocal about the difference between past INEL activities and this kind of weapons work. The Idaho Conservation League position was, "We are, in general, opposed to expansion of all nuclear-related activity at the INEL Site..." Site personnel, on the other hand, began preparing for the new reactor.[20]

INEEL 88-121-1-30

INEEL 88-121-1-18

*Not everyone agreed that the Special Isotope Separation project was right for the INEL.*

DOE next selected INEL as the site for a Special Isotope Separations (SIS) plant to make plutonium for weapons. Not a reactor, the $500 million project would import plutonium from Hanford, use lasers to vaporize it and remove impurities, and then send it to Rocky Flats for fabrication. By-products would remain in Idaho. The project was to be located at the Chem Plant, and soon employees began the complex work of developing this project.[21]

In October 1983, 240 United States Marines had been killed in Lebanon by a terrorist car-bomb. Shocked by the vulnerability of the troops, Congress insisted on a general upgrade in readiness and security against anti-terrorist activity both inside and outside the nation. At INEL, the security force doubled in 1984 and the IDO took delivery of two helicopters by December 1984. Four new guard posts went up around the Site, and DOE attempted to restrict commercial air traffic from flying over the Site. Helicopter surveillance patrols began in 1985.[22]

Eventually, the major nuclear defense activities planned for the INEL, the New Production Reactor and the

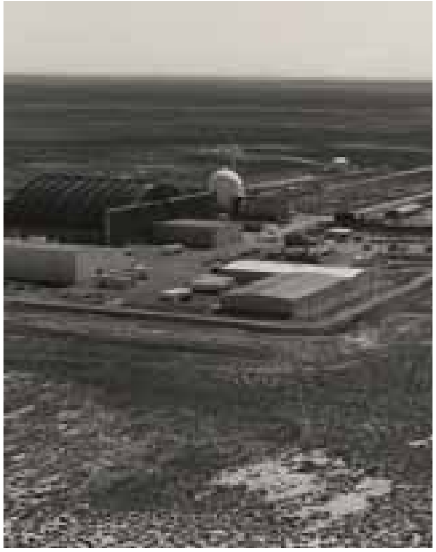
Special Isotope Separations facility, were canceled by DOE, but not because of Idaho protests. Secretary of Energy James Watkins asked Congress in 1990 to cancel the SIS plant because weapons needs could be met with existing plutonium resources. In fact his predecessor, John S. Herrington, had once declared that the nation was "awash in plutonium." The Soviet Union was coming apart, future weapons needs were revised, and a general downsizing of the weapons complex began. The New Production Reactor faded, as Watkins looked into the possibility that a linear accelerator could produce tritium.[23]

Only one major defense project materialized in Idaho, and it had more to do with conventional than nuclear defense. Still, it was as secret as any traditional nuclear weapon. When IDO manager Troy Wade announced it in 1983, he could only describe what it was not: not a reactor, not related to nuclear fusion, and not a space-related project. He said it didn't involve weapons or radioactive hazards.[24]

But the project did involve uranium. And it was intended for non-peaceful purposes, if not directly as a weapon. The project went under construction in the fall of 1983. The United States Army had secretly developed an armor package using depleted uranium for its M1-A1 Abrams Main Battle Tank. The East Idaho Nuclear Industrial Council had been trying to market the empty hangar building at TAN for years, and the building at last found a customer. Its expansive clear space was roomy enough to hide an 82,000-square-foot building three stories high from the eyes of satellites passing overhead. The building—and the remoteness of Idaho—were ideal for the secret manufacturing project.[25]

The junk that had accumulated in the hangar-as-storage-closet over the years was moved out of the way, and the IDO hired Exxon Nuclear Idaho Company to set up shop. Fresh barbed wire went up around the area, and signs went up in the cafeteria warning workers not to discuss classified information. The hangar doors were welded shut. The ANP's never-used coupling station and hatch access to the basement remained in its original place, encompassed as part of a stairway landing and part of a few offices. Because its purpose was secret, Site workers and the press called it Project X. Its official name—Specific Manufacturing Capability (SMC)—gave little away. In 1985 Exxon produced the first production prototype and by 1988 regular shipments headed for Lima, Ohio, where the material was fitted onto the tanks. The project employed five hundred people, most of whom managed to do their jobs without knowing how their product was to be used.[26]

In 1990 the Army announced to the public and to its employees what was



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*Above. Support buildings for Project X went up around the TAN Hangar. Below. An employee appreciation day held in 1991 at SMC gave employees an opportunity to see the M1-A1 Abrams tank in action.*

INEEL 91-0116-2-28

being made. Soon after, the tanks received their first combat experience in the 1991 Persian Gulf War, where they withstood direct hits from enemy fire. The Army decided to produce 1,150 M1-A2 tanks by retrofitting older M1 tanks. The armor production work, with a reduced work force, was expected to keep the hangar occupied until at least the year 2003. The formulas and production processes remained secret, and the Army merely conceded that the armor was denser than lead.[27]

INEL's move to defense programs proved to be a mixed blessing for relations between INEL and the State of Idaho. On the one hand, the new projects boosted employment and budgets at the INEL and, by extension of the economic multiplier, the entire economy of southeast Idaho. On the other hand, the defense build-up aroused the greater energies of pacifists and environmentalists, who mounted vigorous protests across the state. These placed the governor's office in a predicament. John Evans' staff, for example, debated the political hazards involved should he consummate a deal with the IDO: You shut down the Chem Plant injection well, and the governor will support the new defense projects.[28]

More was new at the Chem Plant in the early 1980s than Governor Evans's evaporation pond. A second generation of process facilities was replacing the well-used originals. Beginning in the mid-1970s, new construction had been a constant activity at the Chem Plant. Construction trailers, warehouses, temporary contractor office buildings, and laydown yards cluttered up the complex.

The old Waste Calcining Facility had worn out. Small scratches and pits on the metal surfaces of vessels and pipes attracted deposits of radionuclides that were hard, if not impossible, to remove. Hazards to the maintenance and repair crews were increasing at the same time that exposure standards were becoming more stringent. The designers had not anticipated that waste feed containing fluorides would pass through the pipes and vessels in the plant, but these and other exotic chemicals had helped to age it.[29]

DOE selected the Ralph M. Parsons Company as concept designer of a new calcining facility. It was to meet four main goals: be safer for workers, raise the process capacity from 1,800 gallons to 3,000 gallons a day, handle the chemistry of future wastes, and discharge even less radioactivity into the atmosphere. Every feature of the plant was up for improvement—the heating system, the handling of ruthenium, even the shape of the calciner vessel. Federal rules that had followed from environmental protection laws now required that future decontamination and final decommissioning be considered in the design.[30]

The new calciner started hot operations in 1982. In some ways, its design was a tribute to the original plant. It was in a single building with the process cells below grade. Shielded equipment cubicles next to the cells housed high-maintenance items—although this time they had air locks. Back-up equipment was installed from the start so that a failure would not have to shut down a campaign. More chores could be done remotely, so there were more shielded glass viewing windows and manipulators. Old annoyances such as awkward lifting lugs on heavy objects were eliminated.[31]

The makeover of the Chem Plant included a better air filtration system, a new Remote Analytical Laboratory, and other upgrades. New locker rooms and a cafeteria replaced their worn-out originals. The uranium reprocessing plant itself was rebuilt in stages beginning in 1979. This time, new fuel storage basins were located adjacent to the process building so fuel could move underwater directly to the dissolvers. The arrangement eliminated the tedious loading and unloading of casks for an overland journey of one-third of a mile. The huge pools had 2,600 fuel storage positions. The process cells could dissolve modern fuel elements using hydrofluoric acid. The method had been invented at INEL, so the process was named "Fluorinel." The $200 million plant featured remote- and computer-controlled management of the process. Despite its great cost, the plant was expected to recover enough uranium and other commercial by-products in five years to pay back the cost—and continue efficiently for decades to come.[32]

Beyond the INEL, most of the AEC's old demonstration power plants had long since come to the end of their operational life. Their nuclear fuel, some of which had been exotic or unusual, needed to be removed. If the unfissioned U-235 could not be recovered, it needed secure storage somewhere. The AEC assigned some of it to Idaho, handing the Chem Plant a new mission: storing the fuel. Some of it,

# Reactor Safety Testing

The INEL work in reactor safety was a complex and detailed interaction between the familiar procedures of scientific inquiry: making predictions and then verifying them with empirical tests. Each test confirmed the prediction or helped to refine the next iteration. Computers made it possible to model systems with huge numbers of variables. The safety tests at the INEL involved several interrelated programs, among which were:

## ADVANCED CODE DEVELOPMENT

Predicted the thermal hydraulic behavior of coolant in the primary coolant system based on new models. The models resulted from small-scale experiments, carefully instrumented to obtain accurate data. The models were incorporated in an overall code called RELAP.

## FUEL BEHAVIOR PROGRAM

Tested the performance of fuel pins in conditions of normal and transient conditions. Tests were done in the MTR, ETR, and ATR. The work included the creation and experimental confirmation of a Fuel Rod Analysis Program (FRAP) using the Power Burst Facility.

## FULL-LENGTH EMERGENCY CORE HEATING TESTS (FLECHT)

Using twelve-foot non-nuclear bundles of fuel rods, tests determined the effectiveness of emergency core cooling systems in pressurized-water reactors.

INEEL 82-4005

*Developed at INEL, RELAP5 is a program that gives over 50,000 computational instructions to a large computer. It calculates overall nuclear power plant system responses to accident situations such as the one at Three Mile Island.*

## FISSION PRODUCT BEHAVIOR EXPERIMENTS

Small-scale tests helped assess the accuracy of computer models describing the release of fission products and where they went after a loss-of-coolant accident (LOCA).

## CONTAINMENT ANALYSIS PROGRAM

Experiments were performed at Sandia National Laboratory and in Idaho; additional analytical work was done at the INEL.

## EMERGENCY CORE COOLING SYSTEMS ANALYSIS

Combination of experimental and analytical work that evaluated and predicted how products made by various manufacturers would actually perform. Results of Semiscale and LOFT experiments were part of this program.

## SEMISCALE

Experiments tested and verified computer models of LOCAs. In the event of a leak in a primary coolant system, water pressure would fall, a process called “blowdown.” Semiscale studied this thermal-hydraulic phenomenon in detail.

## LOFT INTEGRAL TEST PROGRAM

An experimental reactor provided empirical data supporting behavior predictions for pressurized-water reactors under LOCA conditions. The program evaluated engineered safety features and assessed the margins of safety in their performance.

like the special graphite fuel used in rocket propulsion experiments in Nevada, could not be stored in water due to undesirable chemical reactions.


AEC-67-7886


INEEL 81-3072

So dry storage cells were added to the Chem Plant landscape. Fuel from Peach Bottom Atomic Power Station, Pennsylvania, and Ft. St. Vrain Nuclear Generating Station, Colorado, eventually arrived in Idaho for safekeeping.

Meanwhile, the power of anti-nuclear protests (overshadowed, some historians think, by the management mistakes of the electric utility industry) was derailing the progress for uranium that scientists and policy-makers had taken for granted since the 1950s. Scientists had expected, first, that breeders would eventually replace water-moderated reactors because only breeders fulfilled the endowment of all uranium, not just the tiny percent of U-235 in the natural metal, as a benefit to human society. Water-moderated reactors had been easier to develop, but they wasted uranium. Second, the nuclear industry would reprocess spent fuel in commercial plants similar to the Chem Plant. Spent fuel would not be stored indefinitely as a waste, but recycled to conserve the resource. Third, the disposition of radioactive waste would in due course yield to both scientific and political solutions.[33]

President Carter and many of his staff believed that civilian nuclear energy offered opportunities for the illicit assembly of nuclear weapons. A Los Alamos physicist named Theodore Taylor contended that it would be easy to divert nuclear materials from commercial operations and make bombs. As a nuclear weapons insider since the Manhattan Project, Taylor's credibility was regarded as excellent by many, and he described his fears in forums such as the *New Yorker* magazine. At the same time, the number of nations in the world which had developed sufficient expertise to conduct nuclear weapons tests grew to include India, which detonated a nuclear device in May 1974. Brazil and Pakistan seemed to be next in line; West Germany was about to send Brazil both a fuel enrichment plant and a fuel reprocessing plant.[34]

*Above. Peach Bottom fuel elements, consisting of uranium and thorium carbides clad in graphite, before they were loaded into the reactor. The reactor went critical on March 3, 1966, with 682 elements loaded in the core. Left. The New Waste Calcining Facility calciner vessel.*

Carter decided to eliminate as many opportunities for the "proliferation" of nuclear weapons as possible. He permanently canceled construction of a commercial fuel reprocessing plant at Barnwell, South Carolina. Henceforth, spent fuel had to be stored in heavily shielded facilities at power plants or elsewhere. Hoping to enlist the rest of the international nuclear community in the cause, Carter then supported an International Nuclear Fuel Cycle Evaluation (INFCE), a technical study of the characteristics—including their potential attraction for illicit diversion—of reactor fuels in use around the world. Carter opposed the Clinch River breeder demonstration, although Congress continued to fund it. Ronald Reagan defeated Carter and threw his support behind Clinch River, but the government's investment in the project was rising at an unacceptable rate. Congress ended the project in 1983.[35]

With reprocessing activities canceled due to fears of proliferation, Clinch River canceled because of spiraling costs, and anxiety about radioactive waste generating political protests all over the country, the old template for the progress of uranium was rendered completely obsolete.

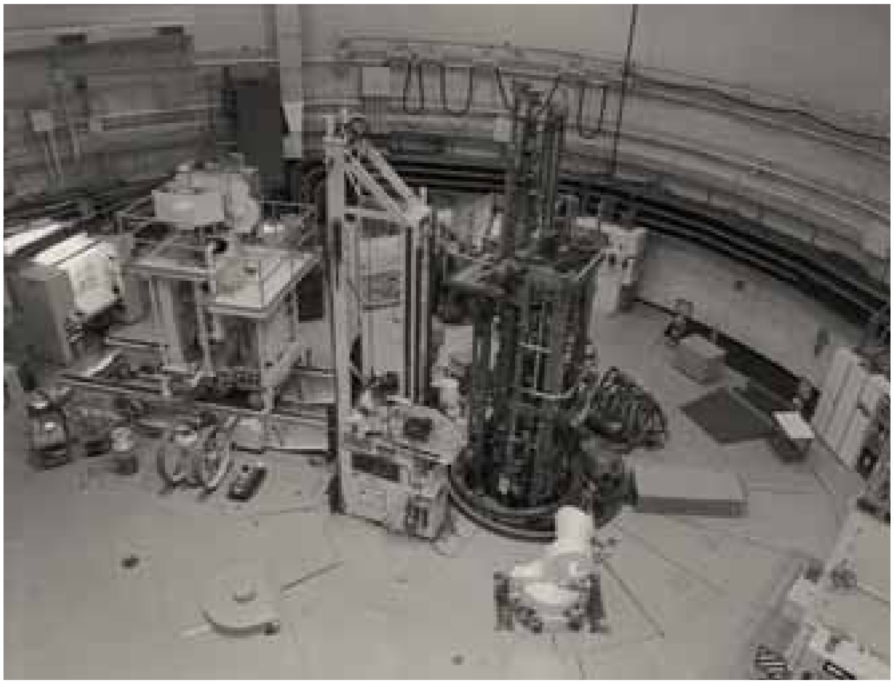
Still, the situation offered someone an opportunity to be brilliant. The death of Clinch River, the fuel for which was to be a uranium oxide, opened the door to a new way of thinking about breeders. At Argonne, physicist Charles Till took charge of Argonne's nuclear reactor program in 1980. Earlier, he had directed the technical work of one of INFCE's working groups. Up until now, the evolution of reactors had flowed more or less from the revelations of science. Society and the environment had been forced to adapt accordingly. Perhaps it was time that a reactor design meet the specifications of society.[36]

That was Till's insight. As he compared Clinch River's oxide fuel to other types, its many disadvantages became startlingly clear. For one thing, the fuel would have to be reprocessed using technology that would purify the plutonium, an imagined opportunity for diversion. Till returned to the idea of a metal fuel along the lines that the EBR-II team had been developing—and recycling on-site—before Milton Shaw had truncated its progress. The old EBR-II fuel was uranium, substantially enriched, but uranium only. A new fuel should contain a mix of uranium and plutonium because the fissile material created in the reactor would include plutonium, and the plutonium—in metal form—should be part of the recycling process. Till said later,

*Metal fuel had a number of advantages. It was cheap, easy to make. The LMFBR fuel was expensive and it needed a huge expensive facility for reprocessing that might be economic if it could serve fifty big reactors, but the problem was getting from the first to the fiftieth.*

INEEL 98-0537

*Above. Well-guarded bunker at the Chem Plant (CPP-651) stores uranium. Below. Operating floor of EBR-II reactor (inside the dome).*



Argonne National Laboratory-West CC5262

*We needed a different kind of reprocessing. It should be cheap, be part of the reactor plant and be as easy to deal with as routine maintenance. Just turn the fuel around. A couple of the old pyroprocessing people at Argonne East said, "We think we can make electrorefining work." They were the best chemists in the world in that field, for they had worked with it before. They had the expertise to recognize that this might be possible.*[37]

So Till and his colleagues developed a new reactor concept. At the time, the Argonne Lab was, like the INEL and other national labs, considering what new initiatives were available in the world of the mid-1980s. Argonne's Board of Governors was asking for proposals. Till prepared one. But first, he made a pilgrimage to visit Hans Bethe. Bethe had been the head of theoretical physics at Los Alamos during the Manhattan Project and was revered as one of the giants of 20th-century physics. Till called on him at Cornell University and described the physics of the new reactor concept.

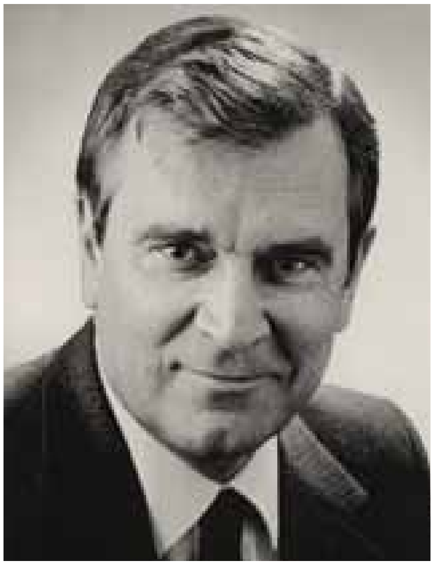
*We packed up and I took the leading person in each technical field with me. We crowded into his small office, and each man gave him a one-hour briefing. As he understood a point, he would say, "Yes, yes, yes," indicating that you should move along.*

*At the end he said, "All the pieces fit. What do you want me to do?"*

Bethe's affirmation that the reactor was sensible, simple, and likely to work was all that Till wanted. Bethe had a reputation as someone who never sugar-coated his opinions, and he stated his opinion of Till's reactor in letters to the President's science advisor, the chairman of the Senate Energy Committee, and Idaho's Senator James McClure. The support of each of these individuals was necessary to start the project. McClure needed assurance that in supporting a project of obvious benefit to his home state, he would be on solid technical ground. Support for the project followed soon after the letters.[38]

Till drove to the Board of Governor's meeting to make his proposal. On the way, he realized that he had not given the reactor a name. He decided on Integral Fast Reactor (IFR). It was a somewhat opaque name that declined to use the baggage-laden word "breeder" but highlighted the integration of the reactor with on-site fuel recycling. Thus prepared, Till began by listing the specifications that the world of the 1980s seemed to be asking of a nuclear reactor.

World population was growing, he said. Demand for electricity would continue to grow. It was important to conserve all energy resources. It was important to limit greenhouse gases and prevent rapid global climate change. Asian and other economies desired a growing share of the world's energy resources if they were to meet rising expectations for a better material life. At the same time, fear of plutonium diversion was curbing nuclear development. Water-moderated reactors were producing plutonium as a waste in their spent fuel, and this material was piling up. Isolating it for centuries was a tremendous expense, and in the United States, at least, the political system had thus far failed to decide where to store it.


Argonne National Laboratory-West

Dr. Charles Till

And finally, after the TMI accident, the public was losing its faith in the safety of nuclear energy.[39]

Taking all that into account, a new reactor should be inherently safe, burn up plutonium in a manner discouraging diversion, and not generate large volumes of long-lasting waste. The IFR met these conditions, and EBR-II in Idaho could prove it.

Argonne committed to the project, DOE agreed to fund it, and Till had his charter. Engineers began to modify EBR-II, the fuel recycling facility, and TREAT for their new mission. No one had made even small experimental quantities of metal fuels for at least fifteen years, but Leon Walters, the head of EBR-II metallurgy, knew how it was done. Within a few months, he had fabricated the fuel elements, and the old routine of carrying out nuclear experiments to prove a principle began once more at the INEL.[40]