CHAPTER TWELVE

REACTORS BEGET REACTORS

You couldn't move forty bright people to Idaho and expect them to quit thinking for themselves or stop being bright.

—Deslonde de Boisblanc—

Bill Johnston got an offer he chose not to refuse. After twenty years with the government, he went to Duluth, Minnesota, in 1954 to work for the Taconite Contracting Corporation. Taconite was preparing to build a pelletizer plant, an undertaking of such size that the company needed to build a town to go with it. The construction phase at the NRTS had by no means ended, but the organization itself was well rooted and on the verge of shifting into an expansive operational mode. Some of Johnston's colleagues felt that he left because he had done what he came to do and that his background, after all, was civil engineering. Others added that the offer was extraordinarily sweet.[1]

Johnston had spent a good part of his energies in 1953 simplifying the management of the testing station. The IDO had set up a technical library, document control systems, and a print shop. Procurement, warehousing, and maintenance systems were in place. The Lost Rivers Transportation Company ran the buses under an IDO contract. Instead of managing these functions itself, the IDO decided to consolidate and place all these activities under the responsibility of Phillips.

The Argonne and Navy programs were under the aegis of AEC offices in Chicago or Pittsburgh, and if the IDO moved to consolidate them under its own jurisdiction, it did not succeed. The Chem Plant was an IDO project, however, and fell into the Phillips net. Chem Plant employees noticed that Phillips' benefits were better than American Cyanamid's, and the transition went fairly smoothly. NRTS employees numbered 1,700 by this time, and the consolidation affected a thousand of them. Dr. Doan assured them that Phillips would "fill job assignments...as far as practicable from applications by present employees." The IDO announced that the change, to take effect in October 1953, would save the government $250,000 a year. Thus streamlined, the NRTS was ready for the changes coming in 1954.[2]

The industrial leaders in the electrical utility business were impatient to develop a nuclear power industry. The spectacular success of the NRTS's first four projects had awakened considerable optimism that nuclear energy, with federal support of nuclear research, would someday mature into a commercial proposition. Largely because of military requirements for nuclear applications, such research funds were plentiful. Companies that wished to enter the nuclear field had many opportunities to do so.

President Dwight D. Eisenhower dominated the formulation of nuclear military policy during the 1950s. Truman before him had felt that atomic weapons would help keep peace, and

President Dwight D. Eisenhower before the General Assembly of the United Nations delivering his address on Peaceful Uses of Atomic Energy, New York City, December 8, 1953.

Dwight D. Eisenhower Library

had committed the country to the development of a hydrogen bomb. He felt that the Soviet Union aspired to dominate the world and regarded the United States as an enemy to be destroyed. In Truman's last three years, annual defense spending went from $13.5 billion to $50 billion. Eisenhower, assuming office in 1953, felt that such huge defense budgets would weaken the economy. "Long-term security required a sound economy," he wrote in his memoirs. His New Look for defense emphasized a military capability to inflict "massive retaliatory damage" on anyone initiating an offensive strike on the United States. The policy lowered the total expenditure on defense but changed the allocation of resources from conventional to nuclear force. The shift fattened the budgets of the U.S. Air Force in particular, because it was the service that would inflict the retaliatory damage.[3]

Eisenhower did not wish to "scare the country to death" by sharing with the public the gruesome scenarios that would come of a nuclear war. He was sensitive to growing business pressure and shared the hopes of scientists for the peaceful atom. The AEC recognized economic nuclear power as a national objective and discussed it with the JCAE in May 1953. Then in December, Eisenhower proposed that the United States and other nations surrender some of the uranium in their stockpiles to international control, thus "dedicating some of their strength to serve the needs rather than the fears of mankind." The Soviet Union didn't agree to the scheme, and it never materialized. Nevertheless, Eisenhower affirmed "Atoms for Peace" as a banner for nuclear commerce.[4]

So the country had two urges, atoms for peace and atoms for war. Both helped grow the NRTS. For the next thirty years, the question of whether nuclear power would eventually produce electricity more cheaply than coal or oil was rarely in doubt; the political debate, rather, was when it would happen and whether AEC policy was helping or hindering the process.

Courtesy of Oak Ridge National Laboratory 55-515

Delegates at the United Nations Conference on the Peaceful Uses of Atomic Energy (1955, Geneva) admire Cerenkov radiation from the small reactor operated by Oak Ridge National Laboratory.

Congress's major step toward a nuclear power industry was to replace the Atomic Energy Act of 1946. The original act had emphasized secrecy and government control of scientific information. It forbade the private ownership or use of nuclear fuel. Clearly, this did not encourage private enterprise. The government's monopoly on nuclear power was once described as "an island of socialism in the midst of a free enterprise economy."[5]

The AEC needed a new legal framework for the federal licensing of power plants and for promulgating safety standards—and for maintaining the United States as a world leader in these areas. As a matter of prestige, it was important that the nation maintain a technological lead in peaceful arenas as well as military. The state of American technology was believed to reflect the superiority of American democracy and capitalism over communism. The new Atomic Energy Act of 1954 shifted American policy and the AEC in this direction.[6]

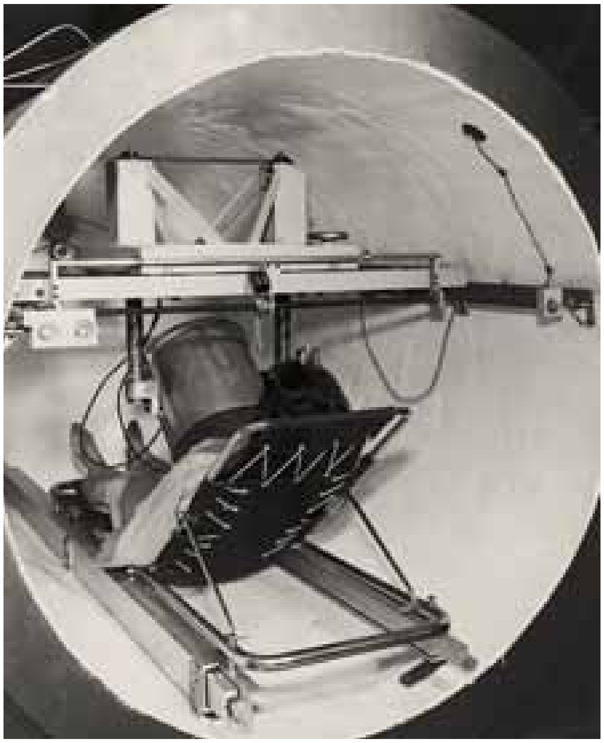
The NRTS already was on a growth trajectory partly driven by creative impulses from within its work groups. At the Test Reactor Area (TRA), the MTR was an instant hit. Like Sun Valley, another Idaho landmark with a global identity, the MTR became so essential and so famous that nuclear literature in the 1950s and 1960s often didn't bother to mention its country or state.

Being at the leading edge of a new industry was impressive enough, but the sheer search for knowledge was the reason Phillips people went to work every day—and stayed all night if a result or reactor startup was expected at midnight or two a.m. For such devotees, there was a bunkhouse at Central, and if those beds were full, it was well known that women's restrooms contained cots.[7]

The pioneering work at the MTR influenced reactor design all over the free world. The Sylvania Electric Products Company was typical of the MTR's many commercial customers. Sylvania wished to manufacture fuel elements. Using two different techniques, the company made eighteen fuel elements using natural uranium. The MTR subjected them to prolonged high-flux exposure—and the scientists observed how both types gradually increased in diameter and decreased in length. Findings such as these helped Sylvania design fuel assemblies that allowed for swelling, which otherwise would choke off the flow of coolant.[8]

If the AEC or home lab scientists at Oak Ridge and Argonne had thought that the Idaho desert would be a passive slate on which experiments would be built, run, and shut down, the Phillips group soon corrected this notion. Opportunities had to be created, problems had to be solved. Innovation was the only answer, and it brought growth, as Deslonde de Boisblanc recalled.

We had a problem at the MTR canal. Apparently the cladding on one of the fuel elements stored there had failed. The fuel was leaching radionuclides into the canal water, but we had no way of determining which element was the bad one. We needed what we didn't have, which was instruments that were sensitive enough to detect a mixture of minute quantities of radioactive elements and tell us what they were. We found a way to solve this problem, and in doing so initiated a program to study the "decay schemes" of the radioactive isotopes which put nuclear spectroscopy on a firm basis.



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Health physicists scrounged the lining of an old Navy gun barrel and invented a whole body counter. Employees were examined regularly.

The AEC Division of Reactor Development funded a special laboratory and a staff for it. This program was very broad and permitted theoretical and experimental studies of the fission products as well as the neutron deficient isotopes produced by bombarding samples in the MTR. This access to the world's highest continuous source of neutrons was just too tempting to resist. But background radiation from weapons tests was a constant annoyance. The solution of that problem was found to be lying on the ground at Central Facilities Area.

We found some thick steel plate that the Navy had left behind from its proving ground days. That stuff was an absolute treasure. It was pre-war steel manufactured before any bomb tests and completely free of man-made radiation. With that we built a special room in which background radiation was reduced to an absolute minimum.[9]

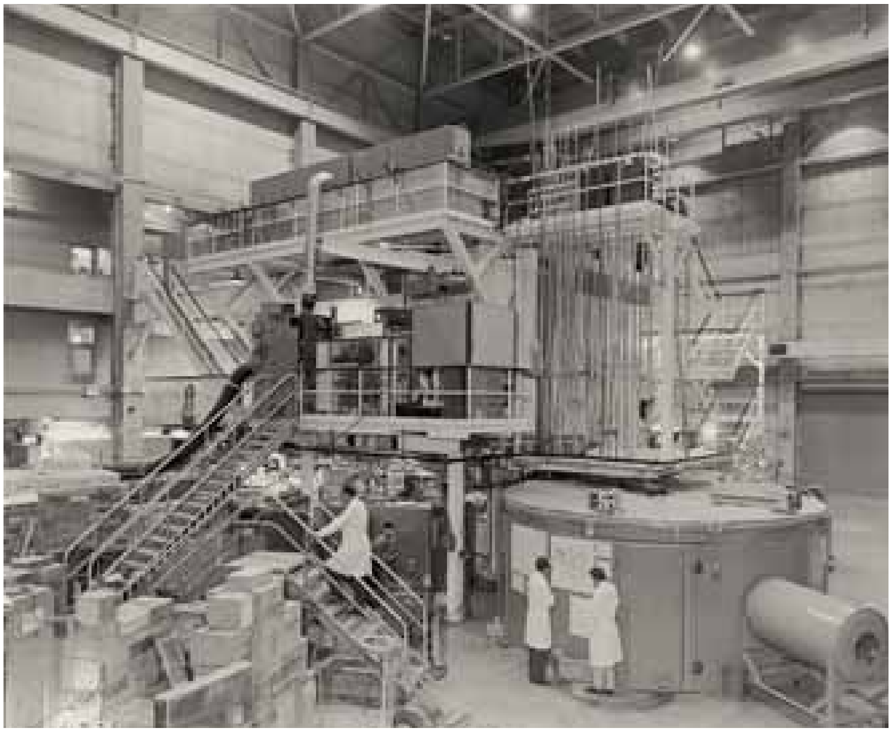
In that special room, physicist Russell Heath led a team of scientists who learned to discriminate among the different energy levels in the radiation being emitted by the several isotopes in the MTR canal water. They also learned the half-life for each and were able then to determine when the damaged fuel element had been placed in the storage canal. Thus, they were able to retrieve it.

Heath went on to standardize the way measurements were made. He prepared a catalog containing the gamma energy spectrum and half-lives of hundreds of radionuclides. Phillips published the first edition in 1958 and several thereafter. The "Blue Book," as the catalog was known, made it possible for researchers elsewhere to profile and identify mysterious elements without spending tedious weeks or months doing so. It was a valuable contribution to the world's store of information about the nature of matter. The catalog continued in use over forty years later.[10]

Another group of physicists under the leadership of Dr. Robert Brugger took full advantage of the MTR's high neutron flux and its beam holes. When unobstructed by shielding, a beam of neutrons streaming out of the reactor was a tool useful for exploring the nature of matter at the level of the nucleus. Although scientists elsewhere had access to spectrometers and other instruments, they did not have access to the neutron flux of the MTR or the availability of hot samples produced within the MTR. The basic idea was to bombard isotopes with neutrons. The atomic nuclei sometimes absorb these neutrons, sometimes bounce them off. Brugger's group studied these interactions and calculated the probabilities for each reaction. This was called "measuring cross-sections," a term originating from the graphic method used to depict the process.

To complicate matters, the probabilities of absorption or scattering are different depending on the energy of the neutrons. The group selected the neutron energy with an instrument called a neutron crystal spectrometer. Another instrument was the fast neutron chopper and time-of-flight spectrometer. Here, it was possible to "chop" the beam of neutrons into pulses as short as a millionth of a second. These pulses would then spread out in time as the neutrons, with different velocities, traveled down a long flight path to the detector array. Whenever the scientists put a sample in the beam, some of the neutrons were removed. From the ratio of the sample-in to sample-out detector signals, the scientists could calculate the total cross section as a function of neutron energy. (This "total" cross section is the sum of the absorption and scattering cross sections.) In the case of samples that scatter the neutrons, the scientists measured the angular distribution of the neutrons and the energy difference between incident and scattered neutrons with a slow neutron velocity selector developed by Dr. Brugger. Brugger also developed a technique to expose samples under millions of atmospheres of pressure to the neutron beams of the MTR.[11]

The work opened a new frontier. No one previously had such access to the exotic radioactive nuclides that the scientists studied at the MTR—or such a team of chemists and physicists making the most of the opportunity. The findings were of incalculable value in the design of reactors. If fertile uranium (or thorium) were to be packed around the



The MTR is all but hidden by experimental apparatus. Samples are being irradiated through beam port at right. Another port is being prepared for an experiment near stile-like stairway. Boxes contain paraffin and other shielding materials. Rack of handling tools stands ready at balcony level.

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core of a reactor, it was essential to know whether the reactor would create more fuel than it consumed and how long the "doubling time" would be. If the process were to take forty years or more, the commercial economics were far less attractive than if the process took, say, fifteen years. Brugger's work meant that reactor designers could select fuels and other materials with some confidence that the reactor would be economically viable. Consequently, scientists from all over the world beat a path to the door of the NRTS.

Phillips scientists made many other moves to expand the capabilities of the MTR. Engineers added a "hydraulic rabbit," which allowed them to run specimens into the reactor without shutting it down. Argonne installed a high-temperature, high-pressure circulating water loop in position HB-2 of the reactor. This permitted a specimen to be exposed to neutron flux along with high-temperature circulating water. The complex apparatus included a heat exchanger, pumps for circulating the water, and the means of regulating temperature, pressure, and other parameters in the water. A Hot Cell Building went into use in the summer of 1954. Operators, shielded behind thick concrete walls and special viewing windows, could handle, photograph, mill, measure, and weigh radioactive samples using remotely operated manipulators.[12]

The AEC authorized Phillips to build a second reactor at the MTR site, the Reactivity Measurement Facility (RMF). Started up in February 1954, this was a small, very low-power reactor located in the east end of the MTR canal. Water was its moderator, reflector, and shield. The RMF used the same kind of fuel assembly as the MTR, but operated only at power levels of one or two hundred watts.

The small reactor, the first of many low-power reactors at the Site, complemented the MTR in that it had a high sensitivity to subtle changes in reactivity. The RMF functioned as a "detector" of neutrons, whereas the large MTR functioned as a "source" of neutrons. The two functions could not be maximized in the same reactor. The RMF enabled analysts to assay new and spent

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Right. Technician demonstrates removal of a fuel element from cask. Crane holds lid while worker uses special tool to remove element. Cask held six to eight elements. Below. The MTR canal contained the small Reactivity Measurement Facility, a low-power reactor. The flat plate in front is a boron-aluminum control element. Samples to be measured went into a "water hole," here filled with a plug.

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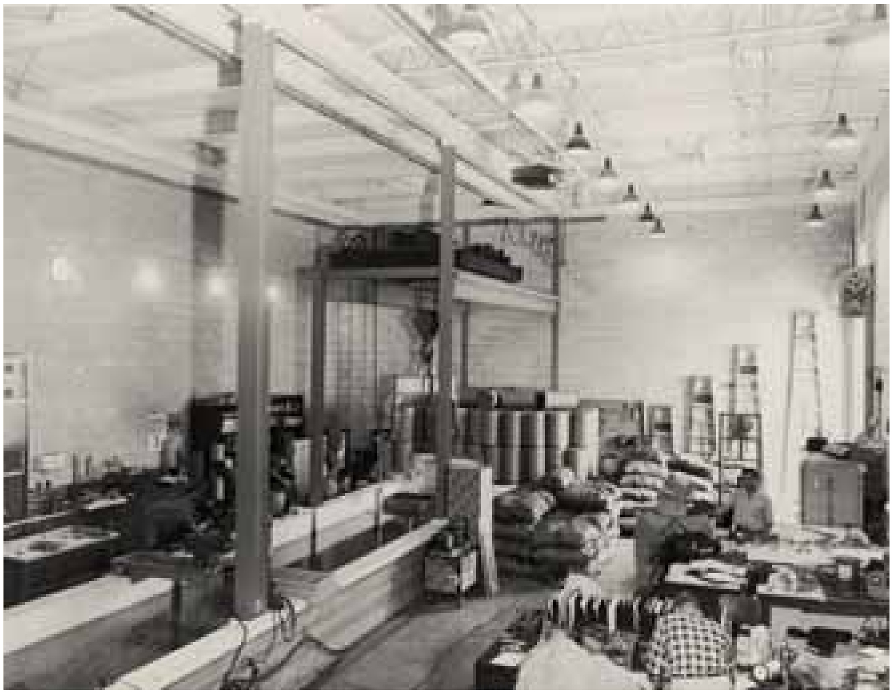
fuel and to study reactivity changes in hafnium, zirconium, and other fuel materials as a function of their total irradiation. One of its first operators, Joe W. Henscheid, recalled:[13]

We'd irradiate a small piece of uranium fuel for several days in the MTR, then take it out and quickly insert it in the RMF. Some of the fission products in the hot fuel sample, although relatively short lived, would decay into very high-cross-section neutron absorbers (so-called "neutron poisons"). Reactor designers, especially in the Navy nuclear program, were interested in knowing more about the adverse effect these neutrons could have in power reactors. In the RMF, as these poisons built up, we had to withdraw control rods to keep the reactor critical. This provided a very precise way to track and measure the effect of these poisons. Recall that this was all being done before we had high-speed computers and elaborate computational modeling that now replace such experimental programs.[14]

The spent fuel cooling off in the MTR canal opened up other research opportunities. The fuel emitted gamma rays—the fresher the fuel the stronger the radiation. They had a penetrating power similar to X-rays and could, among other things, kill pathogens. Many industries in America wanted to know if gamma radiation could do something beneficial for their products. The U.S. Army hoped irradiation would improve the safety and shelf life of food. Phillips built a special Gamma Facility and opened it in 1955. The building was placed outside the MTR exclusion area so that industrial scientists without security clearances, who were not allowed near the MTR, could enter the building and do work.[15]

The spent MTR fuel went to the Gamma building in 26,000-pound carriers shielded with lead, steel, concrete, and water. In the Gamma canal, six feet wide and about sixteen feet deep, the fuel rested near the bottom. Operators placed the elements, now referred to as "gamma sources," into cadmium boxes and parked them at safe distances from each other. Experimenters then dipped their samples into the canal at a pre-selected distance from the fuel element. Depending on how long the sample was to be exposed, its package could be a plastic bag, a can, or a special container with a corrosion-resistant coating. An experimenter could specify the degree of "aging" or "freshness" in the fuel needed for a given test.

Sponsors paid non-profit rates (40 cents per million roentgens plus shipping; $10 minimum charge) and waited their turn on a first-come, first-served basis. They subjected nearly everything imaginable to gamma radiation—meat, grain, fruit, plastics, drugs, coal, gold, diamonds. Hawaii wanted to know if it could improve the shelf life of papayas and mangos and build its export trade. Restless visitors were always on the scene, anxious to learn how gamma rays had changed their product. Typically, the canal contained forty to fifty fuel elements and scores of samples.[16]



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Typical 1955 scene at the Gamma Facility. Sacks of potatoes await experimental irradiation in the canal.

The pressing question in Idaho concerned potatoes. Could irradiation prevent stored potatoes from sprouting? Idaho growers had built their mega-million-dollar industry by learning how to store potatoes for several months, keeping frozen-food plants open profitably long after the glut of the harvest. By the late 1940s, scientists had developed chemical inhibitors to suppress sprouting and other problems for up to nine months. But the goal was a twelve-month industry.[17]

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The University of Idaho owned its own "column" at the Gamma Facility. Walter C. Sparks, one of the researchers at the university's Research and Extension Center at Aberdeen, Idaho, would take ten-pound lots of potatoes, confined in nothing more than open mesh sacks, to the Gamma Facility canal. In an hour's work, he would lean over the railing and lower each sack into the water by means of a long cord. Distance between fuel and potatoes was adjusted for the selected exposure. Some sacks got five minutes, others ten or fifteen. Elsewhere in the canal people might be dunking strawberries or bacon. Sometimes a potato got loose from the sack. Long-handled forceps were handy, and someone would grab the tool and fish for the potato.[18]

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These early experiments demonstrated that irradiation did inhibit sprouting. Another round of experiments in 1963 by the Potato Processors of Idaho demonstrated that irradiated potatoes could be used for satisfactory frozen french fries and some other processed products. However, parallel research with chemical inhibitors had demonstrated that a chemical called CIPC was relatively more simple, required less handling of the potatoes, and presented fewer complications in protecting workers. So the Idaho industry discarded irradiation as the more costly of the two methods despite continuing investigations by competing growers in Canada and Japan into the possibilities of irradiation.[19]

Back at the MTR, the constant cry from customers was "More neutrons! More flux! Faster results!" In response, Phillips modified the reactor to operate safely at forty megawatts. The barrage of questions continued. Will irradiation melt fuel pellets made of this aluminum-uranium alloy? Can we use thulium-170 as a source in medical radiography? Will neutron and gamma radiation improve the coking characteristics of Sewickly coal? How can we design our reactor so it will operate at temperatures of 650 degrees? How will twenty-percent-enriched fuel perform in a high-flux reactor?[20]

Above . A rack of canned food is ready to plunge into a "water column," a rectangular shaft of metal. Air columns also were available. Left. Walter Sparks (in truck) loads up the afternoon's experiment.

Because the MTR itself was an experiment, Phillips tested how well the MTR's own components were holding up. Had the high flux of neutrons caused any structural weakness in the materials within the core area? Using its findings on this and other accumulated experience, Phillips was ready to design the next generation test reactor.[21]

Phillips wanted the next reactor building to have more room on the reactor's operating floor. The MTR work area was crowded with gear, equipment for experiments, and blocks of extra shielding. Office space was in short supply, and people set up desks and work space squatter-like in odd corners, hallways, and at the edges of precious assembly space. The next reactor would have a more generous floor plan.

As for the reactor itself, two of the MTR's chief features—the power level and the test space—were too small. The power level of forty megawatts was too low, unable to produce the concentrated neutron flux required by the military, which was typically on an accelerated schedule. Proposed military applications were pointing in the direction of fuel elements much larger in diameter than the early ones. The test holes in the MTR were no larger than one inch in diameter. "Advanced" research was calling for test holes and loops for thicker and longer elements, more exotic metal alloys, and fuel that would be cooled by gas or air, not only liquid metal or water. These items were simply not going to fit into the MTR. Also, it was difficult in the MTR, if not impossible, to expose the entire length of longer samples to a uniform flux.

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ETR reactor vessel being raised to vertical position during construction in 1956.

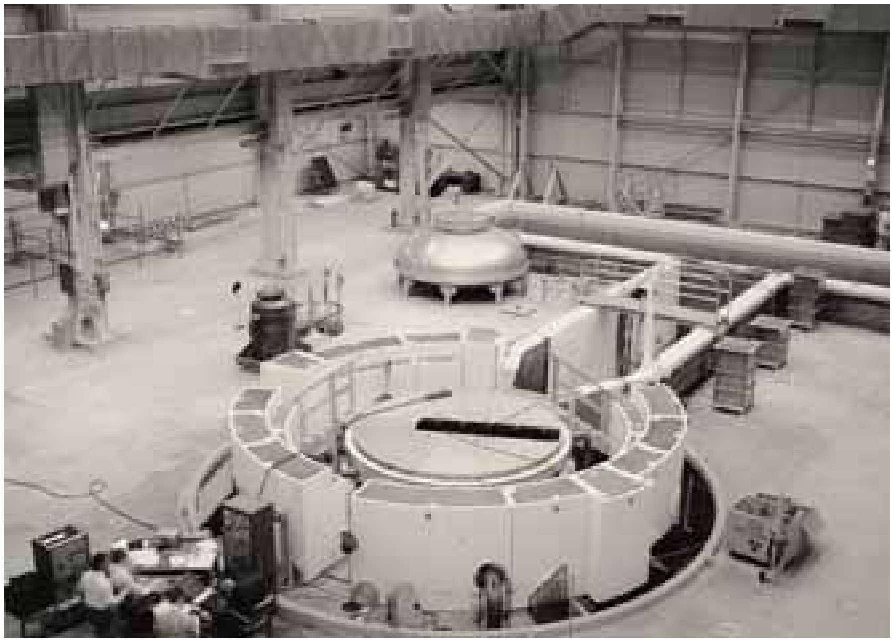
At the same time, demands for low-flux irradiation in the MTR's graphite zone were in less and less demand. That part of the reactor was becoming obsolete. By the end of the 1950s, these zones were used mainly as a place to park cobalt and other isotopes requested for medical uses, a function that reactors elsewhere in the country could perform as well as the MTR.[22]

Thus in 1954, the Phillips team was developing the next test reactor, named the Engineering Test Reactor (ETR). After the AEC approved Phillips' concept, Kaiser Engineers finished the design and built it. General Electric designed the reactor core and its controls. From design to completion, the project took only two years. Like the MTR, the ETR reactor was water-cooled. Unlike the MTR, its control rods were driven through the core from below the reactor, not from above. This arrangement left the area above the reactor available for experiments.[23]

Aside from its higher power level of 175 megawatts, the big change with the ETR was that the samples could be placed directly into the core of the reactor, not just next to it, as with the MTR. The MTR operating experience had indicated that this would be safe and effective.

The ETR fuel was arranged in a rectangular grid with holes here and there for insertion of loops and capsules. Many of the ETR holes were large enough to contain entire fuel elements, not just samples, and the experiments could operate with their own cooling systems independent of the reactor's own cooling system. Like the MTR, the ETR had a companion low-power reactor, the ETR Critical Facility (ETRC), in which the power-perturbing qualities of proposed experiments could be measured safely in advance before being tested in the ETR.

The ETR generated a neutron flux four times greater than the MTR. It went critical for the first time on September 19, 1957. It would serve many of the MTR's old customers, including the U.S. Navy, but the new kid on the NRTS block was the U.S. Air Force, and many of the special ETR loops had been designed to test the fuels required for a special airplane.[24]



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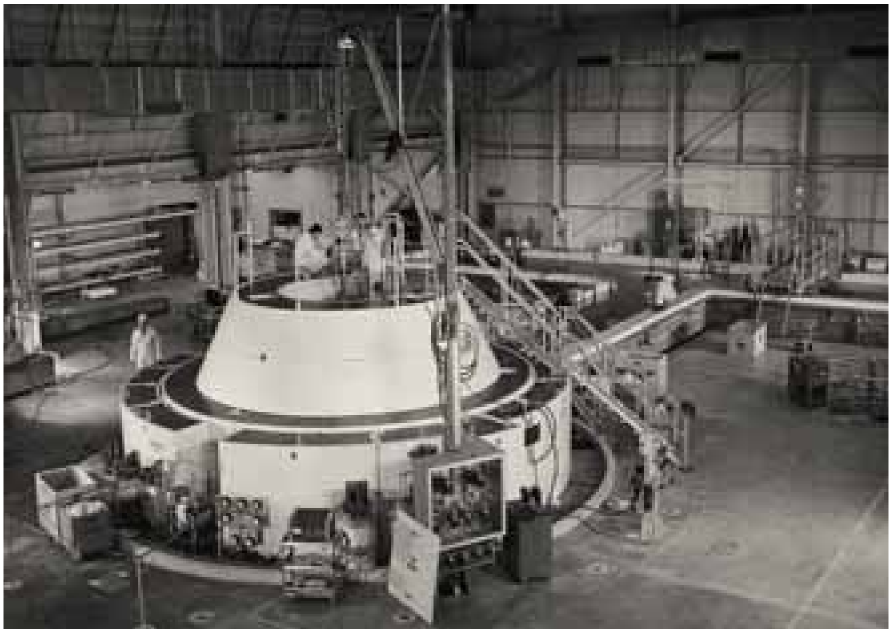

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Above. The ETR being assembled, top removed. Fuel elements were lifted from reactor core and sent through a chute into the canal—all under shielding water. This improved safety and convenience over MTR methods. Below. The ETR with experiments in progress.

The Noble Sky

Oh come with me
to watch the first RADON
When the stars ARGON
As the day KRYPTON
And if the morn be cloudy
You won't ZENON.

MTR shift supervisor's log:
May 6, 1952